

Chapter 168: Surgery for Chronic Ear Disease

Paul R. Lambert, John T. McElveen

The term *tympanoplasty*, which dates from the early 1950s, refers to any surgical procedure involving reconstruction of the tympanic membrane and/or ossicular chain. Various schemes for defining tympanoplasty have been suggested, including Wullstein's classic type I through type VI classification system based on the position of the tympanic membrane relative to the ossicles or cochlear windows (Wullstein, 1956). In this scheme, for example, a type III tympanoplasty involved placing the tympanic membrane on the stapes capitulum (myringostapediopexy) because of an absent malleus or incus. Wullstein's scheme is chiefly of historical interest today because of the significant advances in middle ear reconstruction techniques and prostheses that have occurred in the 1960s and 1970s. No classification system can adequately incorporate the variety of surgical procedures in use and thus, the surgeon must add to the term *tympanoplasty* descriptive words that further explain the operative procedure (ie, *tympanoplasty with incus interposition*, or *tympanoplasty with TORP*). The term *myringoplasty* is interchangeable with the term *tympanoplasty without ossicular reconstruction*.

The variety of techniques used in tympanoplasty surgery and particularly in ossicular reconstruction attests to the difficulty in restoring function to the middle ear transformer that has been impaired by disease, trauma, or congenital deformity. Thus, one is not justified in being dogmatic about a particular surgical approach or prosthesis. This chapter will endeavor to present objectively various surgical techniques and discuss their merits and disadvantages. A foundational review of the physiologic principles involved will be given, and the important historical steps that have enabled us to refine this surgery will be traced.

Physiologic Considerations

As sound waves travel from an air to a fluid medium, 99.9% of the energy is reflected at the air-water interface. This circumstance exists for human hearing and results in a potential 30 dB loss of sound. By matching the low impedance of air with the high impedance of the cochlear fluids, the middle ear functions to prevent most of this sound energy from being reflected. This transformer function of the middle ear is accomplished primarily by the *hydraulic effect*, which is the ratio between the area of the tympanic membrane and the stapes foot plate. For the human ear, this produces a seventeenfold increase in force at the oval window. The hydraulic effect also establishes a differential in the force of the sound energy at the oval and round windows, permitting a traveling wave to be established within the cochlea. The *lever action* of the ossicular chain also contributes to the transformer function of the middle ear, but in a minor way.

A tympanic membrane perforation, depending on its location, can affect hearing by altering both the hydraulic effect and the oval window/round window force differential. A small anterior perforation, for example, which still isolates the round window from direct sound stimulation, should result in less than a 30-dB conductive deficit. On the other hand, a large central perforation with the round window exposed not only disrupts the hydraulic effect, but also allows sound to reach the oval window and round window with similar intensity and phase angle. This alters the traveling wave and results in a conductive deficit

that is larger than 30 dB (Moller, 1983). The addition of ossicular chain disruption to a large perforation may produce a hearing loss of 40 to 50 dB. An even larger conductive deficit can result from ossicular discontinuity behind an intact tympanic membrane. In this circumstance, both the oval and round windows are shielded from the sound pressure and the transformer function of the middle ear is nonoperational.

The frequencies involved in the hearing loss are influenced by the size of the perforation. For example, a small perforation will transmit low-frequency sound to the middle ear, thus diminishing the force of such sounds for tympanic membrane movement. A predominantly low-frequency hearing loss results. As the perforation enlarges, hearing loss occurs over an increasingly higher frequency range (Tonndorf et al, 1976).

Tympanoplasty

History

The modern era of tympanic membrane and middle ear surgery began in the 1950s as Zollner and Wullstein began reporting results on closing tympanic membrane perforations (Wullstein, 1956; Zollner, 1955). Their introduction of the operating microscope during these years furthered this pioneering work. The initial grafting tissue was either a split-thickness or full-thickness skin graft (usually taken from the postauricular area). However, the disadvantages of excessive desquamation and reperforation became apparent and prompted investigation into other grafting materials. During the next decade, results improved as canal skin and various connective tissue grafts were used (House and Sheehy, 1961; Sheehy, 1964; Storrs, 1961). In 1966, Marquet introduced the use of homograft tympanic membranes.

Coincidental with the development of grafting materials was the evolution of several grafting techniques. The overlay or outer surface technique was initially used, but in the early 1960s as connective tissue grafts gained acceptance, the underlay technique became more popular. Today autograft temporalis fascia is the most frequently used grafting tissue, and the underlay technique is the most commonly used procedure to repair a tympanic membrane perforation.

General considerations

Operative considerations

Although various operating room arrangements are possible, we prefer the surgical nurse to be positioned opposite the surgeon (Fig. 168-1). This provides direct transfer of instruments without the surgeon having to take his eyes from the microscope. The patient must be secured to the operating table because frequent rotations of the table toward or away from the surgeon are necessary to optimize surgical exposure. Placing the table in a slight Trendelenburg position helps counteract the natural convexity of the ear canal and improves vision into the posterior and superior recesses of the middle ear.

Patient evaluation

Before consideration of any surgical intervention, it is essential to inspect the ear carefully and define the pathology accurately. An apparently simple tympanic membrane perforation may represent the lateral view of a cholesteatoma eroding the ossicular chain. A chronically draining ear that has been resistant to previous medical and surgical therapy may be a mycobacterial infection or a carcinoma.

In evaluating an ear, it is important to assess the following:

What is the history of onset of the ear infection?

What is the extent and type of the hearing loss?

What is the status of the hearing in the contralateral ear?

Do voice and tuning-fork tests confirm audiometric tests?

What is the condition of the external canal and meatus?

How large is the perforation and is it central or marginal?

What is the status of the tympanic membrane and middle ear mucosa?

Is there an active infection, tympanosclerosis, or other disease?

Are the ossicles involved?

Is the attic involved?

Is a semicircular canal fistula present?

What is the suspected cause of the problem?

Another important question involves eustachian tube function. Although fundamental to successful tympanic membrane and middle ear reconstruction, the ability to assess the function of the eustachian tube accurately remains elusive. Various parameters such as the status of the contralateral middle ear, the incidence of otorrhea with upper respiratory infections, and appearance of the middle ear mucosa provide some indication about eustachian tube function; however, these as well as specific eustachian tube function tests are not highly correlated with operative success. Reversibility of impaired eustachian tube function is also possible as middle ear mucosa reverts to a more normal state or as polypoid or other obstructive tissue is removed at the eustachian tube orifice.

In most routine chronic ears, radiographic studies are not obtained. Only rarely, for example, will a CT scan demonstrate an attic cholesteatoma that was not apparent on physical examination. The CT can be helpful, on the other hand, in delineating a congenital middle ear cholesteatoma. Attempting to demonstrate by CT the presence or absence of facial nerve

involvement or a labyrinthine fistula in the case of chronic ear disease or cholesteatoma is subject to misinterpretation. It is preferable always to suspect these complications at the time of surgery and apply the appropriate surgical technique. The status of the ossicular chain can be assessed by CT, but such preoperative information has little impact on how the surgical procedure is planned. A congenital conductive hearing loss is an exception because in such cases the CT scan can be invaluable in assessing the presence or absence of the oval window, the position of the facial nerve, and the architecture of the cochlea.

Operative techniques

Anesthesia

Tympanoplasty with or without ossicular chain reconstruction can be performed under general or local anesthesia. If the hearing loss is congenital, general anesthesia is always used and EMG needles are placed in the patient's face for facial nerve monitoring. Even if general anesthesia is used, the ear canal, especially the vascular strip and/or postauricular area, is injected with lidocaine (1% or 2%) with epinephrine (1:50,000-1:100,000). To permit time for adequate vasoconstriction, these injections are made before the ear is prepped; the canal injections are made with the aid of the operating microscope.

Incisions

Although various canal incisions have been described, most have as their basis one of two standard approaches: the tympanomeatal flap or the vascular strip. The tympanomeatal flap is created by making longitudinal canal incisions superiorly at the tympanosquamous suture line (approximately at the 12 o'clock position) and inferiorly at the 6 o'clock position. The incisions begin just lateral to the annulus and extend in a curvilinear fashion approximately 8 mm. A transverse incision connects them at their lateral extent, thus forming a U-shaped flap. The skin and periosteal flap is elevated to the annulus, which is lifted from its bony groove. As the tympanomeatal flap is reflected forward, it hinges at the level of the malleus handle, providing good exposure of the posterior mesotympanum (Fig. 168-2).

The vascular strip differs from the tympanomeatal flap in two important respects: it is laterally rather than medially based and it requires a postauricular incision. The superior incision for the vascular strip is made at the tympanosquamous suture line and is carried laterally to the bony cartilaginous junction. The inferior incision is made at the tympanomastoid suture line (approximately at the 3 o'clock position on a left ear or at the 9 o'clock position on a right ear). A postauricular skin incision is made, being certain that it extends far enough forward both superiorly and inferiorly to allow adequate exposure of the bony canal when the ear is reflected forward. The vascular strip is elevated from the posterior canal wall and retracted with the auricle (Fig. 168-3). A portion of squamous epithelium will tear from the posterior tympanic membrane as the skin is elevated; alternatively, an incision can be made medially at the annulus between the two longitudinal incisions to free the vascular strip from the tympanic membrane.

The tympanomeatal and vascular strip approaches to the middle ear each have certain advantages and disadvantages. Elevation of a tympanomeatal flap is usually performed endaurally and a postauricular incision is not required. Replacement of the flap is easily

accomplished and healing is usually rapid and without complication. A relative disadvantage of the tympanomeatal flap is that exposure of the anterior half of the mesotympanum and particularly of the tympanic membrane itself is limited as the flap is reflected anteriorly. A prominent anterior canal wall will accentuate this problem.

The principle advantage of the vascular strip is the excellent exposure of the middle ear. Because the posterior ear canal skin has been elevated with the pinna, there is no flap of tissue to manipulate within the canal other than the tympanic membrane remnant. Compared with the tympanomeatal flap, however, healing of the vascular strip can be more problematic. Critical to good healing is accurate placement of the strip onto the posterior canal wall as the pinna is returned to its normal position.

A variation of the tympanomeatal flap approach to the middle ear is the "swinging door" technique (Palva et al, 1969). In this technique, the tympanomeatal flap is elevated and then bisected. The flap incision is carried through the annulus and tympanic membrane remnant into the perforation. Then, as if opening a swinging door, the inferior and superior leaves of the flap are reflected laterally. The advantage of this technique is better exposure anteriorly because the elevated tissues are reflected onto the superior and inferior canal walls and not over the anterior tympanic membrane and anterior canal wall.

Graft placement

Regardless of the approach to the middle ear, the basic principle is to appose connective tissue to either the lateral or medial surface of the drum remnant and to support that tissue with Gelfoam packing. The terms *medial* and *lateral* refer to the position of the graft relative to the anterior tympanic membrane remnant; in both cases the graft is placed medial to the malleus handle. It is important when supporting the graft anteriorly that adequate packing is placed in the anterior mesotympanum, including the eustachian tube orifice. Graft failure in anterior perforations often occurs because the connective tissue separates from the anterior tympanic membrane remnant due to insufficient support.

In many chronic ears the remaining tympanic membrane will be diseased - either atrophic or calcified. Long-term results are better if these diseased portions of the drum are excised. Preparation of the tympanic membrane remnant must also include excision of a 1- to 2-mm rim of tissue around the perforation. This ensures that any ingrowth of squamous epithelium over the edge of the perforation is removed.

Enlargement of the bony canal

A prominent anterior canal wall, especially in situations of a relatively small bony external canal, can compromise accurate graft placement for anterior tympanic membrane perforations. In such cases, a postauricular incision with reflection of the ear anteriorly can provide a better angle of vision and expose the anterior rim of the perforation. Also, the vascular strip approach, as noted above, may be preferable to the tympanomeatal flap in exposing the anterior sulcus. Occasionally, however, the bony overhang from the anterior canal wall is so large that these maneuvers are still inadequate. When this occurs the bony prominence should be removed with a drill. This will not only optimize graft placement, but will also facilitate postoperative inspection of the ear.

To expose the bony anterior canal wall, the overlying skin is either removed entirely, as described by Sheehy (1977), or is reflected medially. In either case, an incision is made in the outer third of the anterior ear canal (using a Beaver knife with a No. 64 blade), connecting the two previous incisions of either the vascular strip or the tympanomeatal flap. The canal skin and periosteum are elevated from the bone as far as the fibrous annular ligament (Fig. 168-4). If the canal skin is to be removed, this dissection is continued superficial to the fibrous annulus, which is left in its bony sulcus. The superficial squamous epithelial layer of the tympanic membrane remnant is then separated from the middle fibrous layer. The canal skin and attached squamous layer from the tympanic membrane is removed from the ear canal and kept moist in physiologic saline. If the skin is only to be reflected medially, the dissection stops at the annulus and the skin/periosteal flap is reflected back onto the tympanic membrane (Fig. 168-5).

Suction irrigation and a drill (with both diamond and cutting burrs) are used to enlarge the ear canal by removing the anterior (and possibly inferior) canal bulges. Drilling is continued until only a thin plate of bone remains over the temporomandibular joint. This results in an opening of the acute angle that existed in the anterior sulcus. Care must be taken not to disrupt the fibrous annulus or touch the malleus handle with the rotating burr. If the skin has been reflected onto the drum and not removed, it is covered with a piece of Gelfoam or silastic sheeting to protect it during the drilling.

In the lateral surface technique the canal skin is routinely removed, regardless of the degree of anterior canal wall overhang. Additionally, any epithelial remnant must be removed from the remaining tympanic membrane and malleus handle after the bony enlargement has been completed. Deepithelialization will prevent the formation of postoperative epithelial cysts, but it is not required in the medial surface technique because the graft is positioned on the mucosal side of the tympanic membrane remnant.

After drilling, the skin flap is reflected back onto the anterior canal wall in those cases in which it had been left attached medially. If the skin had been completely removed, it is first trimmed to remove any strands of epithelium at the edges that may not evert as it is replaced as a free graft. The canal skin is then positioned such that it overlaps the fascia graft by 1 mm, thus helping to facilitate rapid epithelialization and prevent blunting in the anterior sulcus.

Atelectatic tympanic membrane

The care of the atelectatic, nonperforated tympanic membrane requires special comment. In severe cases the drum is adherent to the promontory and draped over the incus and stapes such that all structures in the middle ear are seen in relief. Surprisingly, many such patients will exhibit only a mild conductive hearing loss (15 dB or less). It is reasonable in those instances simply to examine the ear periodically.

Tympanoplasty should be considered if retained squamous debris and recurrent infection become a problem or if deepening of a retraction pocket into the attic or posterior recesses with incipient cholesteatoma formation becomes evident. Surgery is also advised if the conductive hearing loss is more substantial (eg, > 20 dB). Larger conductive deficits usually imply disruption of the normal incus-stapes articulation.

At surgery, the atrophic tympanic membrane should be excised, leaving only a small anterior and inferior rim with the annulus. There are several possible steps that can be taken to prevent recurrence: the use of tragal cartilage to reinforce the graft; the use of temporary (gel film) or permanent (silastic) sheeting in the middle ear; and placement of a ventilation tube either at the time of surgery or in the early postoperative period.

Summary

Successful repair of a tympanic membrane perforation entails attention to a number of surgical principles, but there are many different approaches by which these can be satisfactorily addressed. Thus, one should not be dogmatic about the overlay versus the underlay technique, the vascular strip versus the tympanomeatal flap incisions, the transcanal versus the postauricular approach, routine versus selective drilling of the anterior canal wall overhang (and removal versus reflection of the anterior canal wall skin), or even the grafting material used (ie, fascia versus perichondrium versus loose areolar tissue). The same surgeon may often use different techniques depending on the size and location of the perforation and the anatomy of the ear canal. For example, the transcanal approach with a tympanomeatal flap and underlay technique is ideal for posterior tympanic membrane perforations. On the other hand, the vascular strip/postauricular approach is well suited when there is restricted exposure of an anterior tympanic membrane perforation secondary to a small external canal or a large bony protrusion from the anterior canal wall.

Regardless of the exact technique used, attention to detail should produce satisfactory results in the vast majority of patients (90% closure rate). Complete closure of the air-bone gap is less predictable, but a 100 dB or less conductive deficit is achieved in approximately 80% of patients (Sheehy and Anderson, 1980).

Ossicular Chain Reconstruction

History

Wullstein's early work in tympanoplasty surgery focused on the tympanic membrane and not on the ossicular chain. There was concern regarding sound protection for the round window, but the problem of an absent ossicle was solved simply by placing the tympanic membrane on the next mobile structure within the ossicular chain; this approach is reflected in Wullstein's tympanoplasty classification scheme mentioned earlier. With the advent of stapes surgery in the late 1950s, efforts to reconstruct the ossicular chain using autogenous or synthetic material began in earnest (Hall and Rytzner, 1957; Shea, 1958).

Despite the many excellent short-term and long-term results from prostheses made of autogenous and homologous cartilage and bone, the success of polyethylene and Teflon pistons in stapes surgery focused attention more on synthetic materials. Soon, however, reports of early and late extrusions of these prostheses, especially in cases requiring contact of the prosthesis with the tympanic membrane or graft, appeared (Sheehy, 1965; Siedentop and Brown, 1966).

In 1974, Shea introduced a polytetrafluoroethylene-vitreous carbon prosthesis (Proplast) designed to overcome the problems of displacement, extrusion, and absorption (Shea

and Homsy, 1974). This material was supplanted in 1978 by a high-density polyethylene sponge prosthesis (Plastipore). A further refinement in the use of Plastipore prostheses was the interposition of cartilage between the platform of the prosthesis and the tympanic membrane to further lessen the possibility of extrusion.

Because extrusion of porous polyethylene could not be entirely eliminated, the search for more biocompatible materials, became the major focus in tympanoplasty surgery during the 1980s. Various alloplasts have been introduced including bioactive glass ceramics and hydroxyapatite (Grote, 1986; Merwin, 1986; Reek and Helms, 1985; Wehrs, 1989). Despite research efforts in the design and biocompatibility of middle ear prostheses, use of autograft and homograft ossicles (ie, sculptured incus or malleus heads) remains an attractive option for the reconstruction of the ossicular chain (Smith, 1980; 1982).

Variables in middle ear surgery

Using today's technology, including the operating microscope, microsurgical instrumentation, and a variety of prosthetic materials, it is possible to *improve* hearing in the majority of patients undergoing ossicular chain reconstruction, at least during the initial years of follow-up. However, restoration of *normal* hearing is unusual, except in cases of surgery for otosclerosis. It is not possible, except in the broadest terms, to predict *a priori* which patients will experience the best functional results. The same variables that limit consistency of results also confound interpretation of the literature on chronic ear surgery.

The most significant variable is surgery for chronic ear disease is the function of the eustachian tube. Despite considerable research on the eustachian tube, particularly in animal models, the ability to quantify eustachian tube function in humans or predict eustachian tube function after tympanoplasty remains elusive. This variable is of obvious importance both in short-term healing and long-term maintenance of tympanic membrane and/or ossicular chain repair.

A second variable is the status of the middle ear mucosa. The presence of active infection, polypoid changes, granulation tissue, or bare bone can all affect subsequent function of an implanted middle ear prosthesis. Although these mucosa conditions are related to eustachian tube function, they can also be independent variables. The concept of staging is based, in part, on this potential problem of imperfect healing of the mucosal lining of the middle ear space. Adhesion formation, for example, can alter the position and/or mobility of a middle ear prosthesis.

The condition of the tympanic membrane is a third variable that can influence the outcome of middle ear surgery. Reconstruction of an ossicular chain defect in an ear with an intact tympanic membrane will, in general, be more successful than the same operation performed on an ear with a large tympanic membrane perforation. In the latter condition, the additional problems inherent in tympanic membrane healing are introduced. Also, judgment of the proper prosthetic length (in cases of columellar-type prostheses) can be more difficult because the final position of the grafted tympanic membrane is less certain than when an intact membrane has simply been elevated to explore the middle ear.

A fourth variable involves the status of the ossicular chain. In cases of an incus interposition, for example, the anterior/posterior relationship between the malleus and stapes is an important variable that influences the stability of the interposed ossicle and the direction of force transmission. The position of the malleus relative to the promontory can also affect reconstruction efforts. The shallow middle ear created by a medially displaced malleus handle makes ossicular reconstruction more problematic than in ears with a normally positioned malleus.

The underlying process itself (disease or trauma) that has caused a specific ossicular defect is a fifth variable. The settings of trauma, chronic otitis media without cholesteatoma, chronic otitis media with cholesteatoma, and congenital ossicular abnormalities present very different challenges. For example, middle ear surgery for cholesteatoma will most likely be more extensive than middle ear surgery for a basilar skull fracture, thus increasing the risk of complications such as scarring or residual/recurrent disease. These complications can have a direct impact on the success of the ossicular work. It is interesting to note, however, that if mastoid surgery is required, the intact canal wall versus canal wall down approaches appear to have little influence on hearing results after middle ear reconstruction (Brackmann et al, 1984).

Finally, the material being used for ossicular reconstruction presents a major variable. The surgeon can choose between autograft material, including bone (ossicle or cortical) or cartilage; homograft material (ossicle or tympanic membrane with attached ossicular chain); or alloplasts made from a variety of biocompatible substances.

The above variables, which usually occur in combinations, have hampered the formulation of a simple yet inclusive classification system for middle ear pathology and subsequent ossicular reconstruction. The issue of results is further complicated by inadequate follow-up periods. Most surgeons consider 3 years to be the minimum follow-up period from which meaningful data can be obtained. Given the difficulty in controlling these variables, care should be exercised in attempting to interpret results across different series.

Staging

An important principle in successful ossicular reconstruction is maintaining (or obtaining) a mucosa-lined air-containing middle ear space. Historically, attempts to reconstruct middle ears that had large areas of abnormal or absent mucous membrane and possible residual cholesteatoma and eustachian tube malfunction often resulted in failure. Staging the surgery when such conditions exist can lead to improved middle ear function and better hearing results.

The goals of the first stage are to eradicate the disease, create an intact tympanic membrane, and prevent adhesions from forming between the tympanic membrane and the promontory. Silastic sheathing can be used to splint the middle ear and prevent such adhesions (Sheehy, 1973). The authors use Silastic that is 0.04 inches thick because thinner Silastic can be displaced by scar tissue. The extrusion rate for Silastic is less than 1%. A ventilation tube also may be used at the time of surgery (or postoperatively) to maintain a middle ear space. At the second stage, the Silastic is removed, any residual disease is managed, and the ossicular reconstruction is performed.

Middle ear implants

Fundamental to successful middle ear reconstruction is the establishment of a firm connection between the inner ear fluids and a tympanic membrane with a large, vibrating surface. The connecting prosthesis should be inert and have a low propensity to fix to surrounding bone. It should accommodate placement under some tension without extruding or otherwise causing erosion of the tissues with which it interfaces. A recent survey of 160 members from the American Otological Society and The American Neurotology Society found that the two most frequently used implants in middle ear reconstruction were autograft/homograft ossicles and Plastipore TORPs and PORPs (Emmett, 1989). The numerous materials and designs of middle ear prostheses in use today prove that an ideal prosthesis remains elusive.

Homograft/autograft ossicles

Homograft or autograft ossicles were among the earliest materials used to reconstruct a defective ossicular chain (Farrior, 1960). Although extrusion is uncommon, fixation of the ossicle to adjacent bone such as the canal wall or oval window niche can be a problem. The use of a sculptured or fitted incus (obtained from a commercial tissue bank or prepared by the surgeon during the operative procedure) reduces the bulk of the prosthesis and lessens the risk of bony fixation.

An ideal setting for using an ossicle in middle ear reconstruction is when the incus is diseased but the malleus and stapes are intact. Also desirable is a favorable relationship between these two ossicles such that the malleus neck is positioned near the oval window. A fitted incus prosthesis can then be placed between the malleus and stapes capitulum or directly on the oval window if the stapes arch is absent (Fig. 168-6).

In some ears, the malleus-oval window relationship is unfavorable or the malleus is absent or diseased. A TORP or PORP would be our choice in such circumstances. Another option, particularly for those preferring ossicular prostheses, is to remove the tympanic membrane with the attached malleus and reposition it so that a favorable malleus-oval window relationship is established. In ears with an absent malleus, a homograft tympanic membrane with attached malleus handle could be used, followed by an interposed incus (Lesinsky, 1986).

Allografts

Alloplastic middle ear implants are attractive for middle ear reconstruction for a number of reasons, including availability, sterility, and, in the case of the bioactive implants, direct bonding at contact points (ie, ossicular chain remnants or the tympanic membrane).

Frequently used implants differ in their biocompatibility properties and the methods by which stability is achieved. Plastipore, for example, is a high-molecular-weight polyethylene sponge that is classified as bioinert. Plastipore prostheses are columellar in design and are placed between the tympanic membrane and either the stapes capitulum (PORP) or stapes footplate (TORP). Plastipore is 70% to 90% porous with an average pore size of 250 microg. Stability of the prosthesis is achieved by ingrowth of host tissue.

Histologic studies of Plastipore prostheses explanted after months to years within the middle ear have shown a cellular infiltrate consisting of fibroblast, capillaries, and foreign-body giant cells. The structural integrity of the prostheses appeared intact with no histologic evidence of degradation (Makek et al, 1988).

Ceravitol (80% to 90% weight composition SiO₂, CaO, and P₂O₅); Bioglass (95% weight composition SiO₂, CaO, Na₂O); and Hydroxyapatite (Ca₁₀(PO₄)₆(OH)₂) are classified as bioactive, and achieve stabilization within the middle ear by chemical rather than mechanical bonds (Merwin, 1986; Reck and Helms, 1985; Shea and Homsey, 1974; Siedentop and Brown, 1966). Hydroxyapatite, which closely resembles the mineral matrix of bone, is available in both porous and dense forms. In the former, ingrowth of bone into the implant has been observed in addition to the chemical bonding. All the ceramic implants are covered by a mucous membrane within 1 week after implantation. In most cases, these prostheses are columellar in shape, similar to the Plastipore TORPs and PORPs. Notable exceptions are the hydroxyapatite incus replacement and incus-stapes prostheses designed by Wehrs (1989). Like homograft or autograft ossicles, ceramic prostheses require a drill for contouring; Plastipore can be shaped with a knife.

Theoretically, bioactive implants would be better tolerated in the middle ear than bioinert prostheses. Initial results suggest that this is the case. Brackmann et al, for example, noted a 7% extrusion rate for Plastipore TORPs and PORPs in 1042 cases who were followed from 6 months to 4 years (Smith, 1980). Grote found only 2 extrusions (1.2%) in 170 incus and incus-stapes hydroxyapatite prostheses followed for an average of 5 years (Grote, 1990).

Operative technique (Plastipore)

As noted previously, successful ossicular reconstruction can be performed using a variety of techniques. The following discussion will describe one technique for the use of Plastipore PORPs and TORPs. It is assumed that the ear being operated upon is disease-free, with an air-containing middle ear space and a functioning eustachian tube.

If the stapes arch exists, the Plastipore PORP is interposed between the capitulum and the posterior tympanic membrane. To decrease the likelihood of extrusion, cartilage is used to cover the platform of the prosthesis. If the stapes arch does not exist, a Plastipore TORP can be placed directly from the mobile footplate to the tympanic membrane, also with a cartilage interface (Fig. 168-7). Neither a PORP nor a TORP requires an intact malleus.

A local or general anesthetic can be used. A tympanomeatal flap that is more lateral than a stapes flap is elevated. Incisions should not extend to the annulus but should stop several millimeters from it. This will present a more stable tympanic membrane, allowing for a more precise determination of the length of the prosthesis. Also, these incisions will not be drawn over the middle ear space when the tympanic membrane is tented up by the prosthesis.

The tragal cartilage is obtained through an incision on the posterior edge of the tragus. Perichondrium is removed and a 4 x 4 mm piece of cartilage is prepared. The cartilage is thinned such that a slight dome shape is created. The shaft of the PORP or TORP is cut to allow the prosthesis just to bridge the distance from the tympanic membrane to the stapes capitulum or the stapes footplate. The addition of the cartilage should then cause a slight

tenting of the tympanic membrane. If the malleus is intact, the tensor tympani tendon should be cut and the manubrium dislocated outward. This will provide a deeper middle ear space and flatten the drum surface. Small pieces of saline soaked Gelfoam are placed within the middle ear to support the prosthesis and the external canal is filled with Cortisporin-soaked Gelfoam.

Results

Results using various middle ear reconstruction techniques are shown in Table 168-1 (Brackmann et al, 1984; Grote, 1990; Lesinsky, 1986; Reck and Helms, 1985; Wehrs, 1977). It should be noted that the authors quoted have had considerable experience with their particular technique, and that the same degree of success may not be readily achieved by other otologists. The differences in follow-up periods and numbers of cases should also be noted. In general, long-term closure of the air-bone gap to within 20 dB when the stapes is intact can be achieved in approximately 66% of the patients; when the stapes is absent, this number falls to approximately 50%.