Ossicular Reconstruction

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Grand Rounds Presentation
The University of Texas Medical Branch
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June 29, 2009
Introduction

- Etiology of ossicular disruption
- Anatomy
- Pathophysiology
- Operative Techniques
- Complications
Introduction

- Etiology of ossicular disruption
- Anatomy
- Pathophysiology
- Operative Techniques
- Complications
Etiology

- **Fixation**
  - Malleus head ankylosis (idiopathic)
  - Ossicular tympanosclerosis
  - Scar bands in chronic otitis media

- **Discontinuity**
  - Trauma
  - Erosion by chronic otitis media/ cholesteatoma (most common)
    - Eroded incudostapedial joint (80% of patients)
    - Absent incus
    - Absent incus and stapes superstructure
Introduction

➢ Etiology of ossicular disruption
➢ Anatomy
➢ Pathophysiology
➢ Operative Techniques
➢ Complications
Anatomy

- The normal conducting apparatus of the middle ear consists of an intact tympanic membrane and three ossicles connected in series.
- Any disruption of these components can cause conductive hearing deficits.
Tympanic Membrane

- The orientation of the TM is slightly oblique to the sagittal plane; the TM is roughly conical, pointing medially.
- The handle of the malleus is firmly attached to the medial aspect of the TM.
- The TM is divided into two parts: the pars flaccida (the portion superior to the insertion of the manubrium) and the pars tensa.
- The point at which the inferior end of the manubrium inserts into the TM is called the umbo.
The malleus has two main parts: the manubrium, which adheres to the tympanic membrane, and the head, which articulates with the incus. The malleus head lies in the epitympanic recess.

The manubrium also has two processes: one anterior and one lateral.

The region between the manubrium and the head is called the neck of the malleus.

The chorda tympani crosses the medial surface of the malleus neck.
The incus is divided into 3 principal parts: a body and two processes (named short and long, respectively).

The head of the incus articulates with the head of the malleus in the epitympanic recess.

At the end of the long process of the incus is a small region called the lenticular process. The lenticular process articulates with the head of the stapes.

The short process of the incus is attached to the cavity wall by the posterior incudal ligament.
As the name implies, the stapes looks like a stirrup. It has four components: a footplate, two crura (posterior and anterior), and a head.

The head of the stapes articulates with the lenticular process of the incus.

The footplate of the stapes covers the oval window.
Introduction

- Anatomy
- Etiology of ossicular disruption
- Pathophysiology
- Operative Techniques
- Complications
Pathophysiology

- The acoustic resistance to the passage of sound through a medium is termed *impedance*.
- The transduction of vibratory energy from the air in the external auditory canal (low impedance) to the cochlear fluids (high impedance) is possible as a result of the impedance-matching function of the middle ear.
- Three levers accomplish the required pressure transformation for transduction.
The attachment of the tympanic membrane at the annulus amplifies the energy at the malleus because of the elastic properties of the stretched drumhead fibers.

Because the annular bone surrounding the tympanic membrane is immobile, sound energy is directed away from the edges of the drum and toward the center of the drum.

The malleus receives the redirected sound energy from the edge of the drum because of the central location of the manubrium.
In physics and geometry, the catenary is the theoretical shape a hanging chain or cable will assume when supported at its ends and acted on only by its own weight. The curve is a hyperbolic cosine which has a U-like shape, similar in appearance to a parabola.
Ossicular Lever

- The malleus and incus acting as a unit, rotate around an axis running between the anterior malleal ligament and the incudal ligament.
- The gain of the ossicular lever is the length of the manubrium of the malleus divided by the length of the long process of the incus (approximately 1.3:1).
- The ossicular lever taken alone produces a small mechanical advantage for sound transmission.
- The catenary lever is tightly coupled to the ossicular lever, because the tympanic membrane is extensively adherent to the malleus handle.
- Corrected calculations reveal a combined catenary-ossicular lever ratio of 1:2.3.
Hydraulic Lever

- The hydraulic lever acts because of the size difference between the tympanic membrane and the stapes footplate.
- Sound pressure collected over the area of the tympanic membrane and transmitted to the area of the smaller footplate results in an increase in force proportional to the ratio of the areas.
- The average ratio has been calculated to be 20.8:1.
- Taking the three levers together, the middle ear offers a theoretical gain of approximately 34 dB.
Ossicular Coupling

- Ossicular coupling refers to the true sound pressure gain that occurs through the actions of the tympanic membrane and the ossicular chain.
- The true gain of the middle ear is less than the theorized 34 dB.
- The pressure gain provided by the normal middle ear with ossicular coupling is frequency dependent.
- The actual mean middle ear gain is 20 dB at 250-500 hertz (Hz), reaching a maximum of 25 dB at 1 kilohertz (kHz), and then decreasing at about 6 dB per octave at frequencies above 1 kHz.
Ossicular Coupling

- The changes in gain above 1 kHz are caused by portions of the tympanic membrane moving differently than other portions, depending on the frequency of vibration. At low frequencies, the entire tympanic membrane moves in one phase. Above 1 kHz, the tympanic membrane divides into smaller vibrating portions that vibrate at different phases.
- Another factor is slippage of the ossicular chain, especially at frequencies above 1-2 kHz. Slippage is due to the translational movement in the rotational axis of the ossicles or flexion in the ossicular joints.
- In addition, some energy is lost because of the forces needed to overcome the stiffness and mass of the tympanic membrane and ossicular chain.
Middle Ear Aeration

- Ossicular coupling is impaired when the middle ear space (including the mastoid cavity) is reduced.
- The difference in pressures between the external auditory canal and the middle ear facilitates tympanic membrane motion.
- In the normal ear, the middle ear air pressure is less than the pressure in the external canal.
- When the middle ear space is reduced (eg, by chronic ear disease or canal wall down surgery), the impedance and pressure of the middle ear increase relative to the external canal because the impedance of the middle ear space varies inversely with its volume.
- This reduction in pressure difference leads to a subsequent reduction in tympanic membrane and ossicular motion.
- The minimal amount of air required to maintain ossicular coupling within 10 dB of normal has been estimated to be 0.5 mL.
Austin (1978) identified five categories of anatomic defect and described each within the context of the associated prototypic hearing loss.

The first category, tympanic membrane perforation with undisturbed ossicular continuity produced a hearing loss that was linearly proportional to the size of the perforation (loss of areal ratio + loss of catenary lever).

The degree of hearing loss, flat across speech frequencies, was not altered by the location of the perforation on the drumhead.
The second category, tympanic membrane perforation combined with ossicular disruption occurred in approximately 60% of Austin's patients and was the most common form of conductive hearing loss requiring surgical therapy.

The incudostapedial joint was the most vulnerable ossicular articulation.
Pathophysiology

- The third category, total loss of the tympanic membrane and ossicles created a condition wherein sound pressure contacted the oval and round windows simultaneously, resulting in partial phase cancellation of the sound wave in the cochlear fluids.

- Conductive hearing loss was flat across speech frequencies and averaged 50 dB

- More complete phase cancellation caused increased hearing loss compared with patients with partial perforations.
Pathophysiology

- The fourth category included those patients with ossicular disruption behind an intact tympanic membrane. This defect resulted in a maximal conductive hearing loss of 60 dB.

- The intact eardrum reflected sound energy back into the external auditory canal, causing an additional 17-dB conductive loss above what was expected from removal of the hydraulic and catenary-ossicular lever action.

- The decreased sound pressure also reached the round and oval windows nearly simultaneously, inducing phase cancellation in the labyrinthine fluids.
The fifth category described a variety of congenital malformations with ossicular disruption and closure of the oval window. Also included were cases of obliteratorative otosclerosis with closure of the oval and round windows behind an intact drum. The expected flat loss from such a defect is 60 dB.
Preoperative Assessment

- The goal of ossicular chain reconstruction is better hearing, most typically for conversational speech.
- Patient selection for ossicular reconstruction is largely based on the preoperative audiogram and on the potential to regain serviceable hearing.
- Bringing the operative ear to within 15 dB of the contralateral ear will enhance binaural input to auditory centers; A patient's perceived hearing improvement is best when the hearing level of the poorer-hearing ear is raised to a level close to that of the better-hearing ear.
- In patients with severe mixed hearing loss, ossicular reconstruction can be considered, because it may enhance the use of amplification.
Contraindications

- Acute infection of the ear is the only true contraindication.
- Acute infection will most likely result in poor healing, prosthesis extrusion, or both.
- Relative contraindications include persistent middle ear mucosal disease, tympanic membrane perforation, and repeated unsuccessful use of the same or similar prostheses.
Malleus Head Fixation

- Idiopathic malleus head fixation occurs in the epitympanum.
- 2 different surgical techniques are used in the treatment of malleus fixation syndrome.
- The attical fixation can be removed via a transmastoid approach without disruption of the ossicular chain.
- Alternatively, an ossiculoplasty can be performed via a transcanal approach, removing the malleus head with the incus and reconstructing by incus interposition or by PORP.
- Martin (2009) reported a retrospective study including 24 patients (25 ears).
- The study concluded that there was no statistically significant difference between the 2 surgical techniques when post-op hearing was considered.
**Incus Erosion**

- Some form or degree of incus deficiency is the most common ossicular defect encountered.
- The goal of surgery is to reestablish the mechanical connection between an intact tympanic membrane and the oval window.
- This can be accomplished by a variety of techniques utilizing a variety of materials.
Mildly eroded incus

- The incudostapedial joint and the lenticular process of the incus are the most common sites of ossicular discontinuity.
- This defect can lead to an air-bone gap of up to 60 dB.
- When erosion is limited to the most distal portion of the incus and when the incus and the malleus are mobile, a limited reconstruction can be performed.
Mildly eroded incus

- Applebaum designed a hydroxyapatite prosthesis for defects of the incus long process.
- The Applebaum prosthesis is a rectangular piece of hydroxyapatite with a groove through the proximal end extending the length of the rectangle. The groove stops short of penetrating the distal end of the rectangular prosthesis. At this distal end of the groove, a circular hole passes through the floor of the groove. The groove is designed to accommodate the remnant of the incus long process. The circular hole receives the stapes capitulum.
- The prosthesis is placed by gently lifting the long process of the incus and sliding it into the groove. Then the hole of the prosthesis is placed onto the stapes head. This procedure results in a stable connection requiring no further packing or tissue adhesion.
Advantages of the Applebaum prosthesis include:

- The prosthesis reliably bridges incus long process defects of up to 3 mm. It does not tend to loosen and lose continuity over time.
- The prosthesis avoids technical difficulty and time involved in constructing bone or cartilage bridges.
- It precludes removal of the incus for refashioning, and consequently it spares unnecessary destruction of the incudomalleal joint.
- The prosthesis can be immediately available in the operating room, saving the patient from unnecessary anesthesia time.
Absent Incus

- More extensive erosion of the incus requires a more extensive reconstruction.
- Ossicular continuity can be restored between the stapes and manubrium of the malleus (if present).
- Alternatively, a “strut” or “columella” may be formed by an implant bridging from the capitulum or footplate to the tympanic membrane.
Autograft

- Interposition of incus body as a bridge between the stapes and the malleus was the original ossicular reconstruction surgery.
- If the incus is unavailable, the malleus head may be used.
- This type of autograft is considered by some to be the procedure of choice.
Figure 24-4  Fitted incus prosthesis being put into position with a right-angle hook.

Figure 24-5  Fitted incus prosthesis in position between the malleus and the capitulum of the stapes.
Incus interposition should only be considered when the angle between the long axis of the stapes capitulum and malleus handle is favorable (preferably <30°).

Angles more than 45° prevent proper sound transfer between the stapes and malleus.

Specifically, some sound energy is converted into an inefficient rocking motion at the footplate if the manubrium is too far anterior to the stapes.
Autograft

- **Disadvantages**
  - Prolonged operative time
  - Displacement
  - Complete resorption
  - Possibility of autograft harboring microscopic cholesteatoma
  - Disease process may have eroded available ossicles
  - Poor fit if the stapes superstructure is absent

- **Advantages**
  - Low extrusion rate
  - No risk of transmitting disease
  - Low cost
  - Biocompatibility
  - No necessity for reconstitution
  - Fully biocompatible
Homograft

- Irradiated homograft ossicles and cartilage were first introduced in the 1960s in an attempt to overcome some of the disadvantages of autograft implants.
- These have now fallen out of favor
- Disadvantages
  - Must be stored in special conditions
  - Risk of transmitting diseases (e.g., AIDS, Creutzfeldt-Jakob disease).
- Advantages
  - Same as autograft
A variety of synthetic materials have been used to manufacture a variety of prostheses. These allografts are the most commonly used materials for ossicular reconstruction today.

Disadvantages
- More expensive
- Higher extrusion rate (controversial)

Advantages
- Readily available
- Presculpted
<table>
<thead>
<tr>
<th>Material</th>
<th>Autograft</th>
<th>Homograft</th>
<th>Allograft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extrusion rate</td>
<td>Very low</td>
<td>Very low</td>
<td>Low (whenever in contact with tympanic membrane)</td>
</tr>
<tr>
<td>Ease of handling</td>
<td>Technically challenging—must fashion intraoperatively</td>
<td>Technically straightforward—easily customized</td>
<td>Technically straightforward—select from various sizes</td>
</tr>
<tr>
<td>Availability</td>
<td>Must harvest and fashion</td>
<td>Immediately available</td>
<td>Immediately available</td>
</tr>
<tr>
<td>Operative time</td>
<td>Longest</td>
<td>Short</td>
<td>Short</td>
</tr>
<tr>
<td>Risk for residual disease</td>
<td>Possible</td>
<td>Unlikely</td>
<td>Unlikely</td>
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<tr>
<td>Risk of transmitting disease</td>
<td>None</td>
<td>Hypothetical</td>
<td>None</td>
</tr>
</tbody>
</table>
Plastipore and Polycel

- In the late 1970s, a high-density polyethylene sponge (HDPS) that had nonreactive properties was developed. HDPS has sufficient porosity to encourage tissue ingrowth.

- The original form was a machined-tooled prosthesis (Plasti-Pore); a more versatile manufactured thermal-fused HDPS (Polycel) arrived later. This latter form permitted coupling with other materials, such as stainless steel, thus lending itself to a wide variety of prosthetic designs.

- Clinical experience has shown the necessity of covering these HDPS alloplasts with cartilage to minimize the incidence of extrusion. Extrusion rates have averaged 3-5% in large series with 5-10 years of follow-up monitoring.
Hydroxyapatite

- Hydroxylapatite is another bioactive material used for middle ear reconstruction. The nonporous and homogenous nature of dense hydroxylapatite resists penetration by granulation tissue.
- Hydroxylapatite is a polycrystalline calcium phosphate ceramic that has the same chemical composition as bone.
- It forms a direct bond with bone at the hydroxylapatite/tissue interface. If placed next to the scutum, osseointegration can occur, with subsequent conductive hearing loss.
- With time, hydroxylapatite implants gradually become completely covered by an epithelial layer. The final epithelial layer contains all cell types characteristic for the middle ear, indicating good biocompatibility of the implant material.
Fig 1. HA ossicular prostheses: (left to right) TORP, PORP, and Kartush incus strut.
Titanium

- Titanium is another common alloplastic material. Studies in rabbits have shown that within 28 days after implantation, a thin, noninflamed, even layer of epithelium forms over the inserted implant. Similar results in human studies have shown the same type of reactivity. Titanium forms a biostable titanium oxide layer when combined with oxygen.

- The properties of titanium make it possible to manufacture an extremely fine and light prosthesis with substantial rigidity in the shaft.

- Furthermore, differential processing of the material surfaces triggers various tissue reactions. For example, rough-milled surfaces are most appropriate in areas that contact cartilage or the stapes head or footplate.

- Conversely, the smoother the surface, the less connective tissue reaction occurs, and the epithelial covering is minimized.
Titanium

- As far back as 1993, a group of surgeons designed the total (Arial) prosthesis and the partial (Bell) prosthesis.
- These are available commercially from Kurz.
- In 1996, Spiggle and Theis introduced new titanium prostheses that can be trimmed intraoperatively to the appropriate length.
Which Prosthesis?

An otologic surgeon must choose his prosthesis based on the best chance of successful hearing restoration and the lowest chance of complications.
Defining Success

- Attempts have been made to standardize reporting 1995 guidelines of the AAO-CHE.
- Pre and postoperative air-conduction and bone-conduction thresholds are measured at 4 designated frequencies (0.5, 1, 2, and 3 kHz), then averaged.
- Success is defined as a mean postoperative air-bone gap of less than 20 dB and is the main outcome considered for this talk.
Prognostic Factors

- It is clear that optimal results depend not only on the qualities of the prosthesis, but also on the environment in which it is placed and the surgical techniques used.
Prognostic Factors

- Austin (1972) defined four groups in which the incus had been partially or completely eroded:
  - A, malleus handle present, stapes superstructure present (60% occurrence)
  - B, malleus handle present, stapes superstructure absent (23%)
  - C, malleus handle absent, stapes superstructure present (8%)
  - D, malleus handle absent, stapes superstructure absent (8%)
Prognostic Factors

- Kartush (1994) proposed a scoring system called the middle ear risk index (MERI) to form an index score to determine the probability of success in hearing restoration surgery.
- MERI is used to describe the preoperative middle ear environment at the time of ossiculoplasty.
- It incorporates different classifications of middle ear disease and ossicular status, including Austin’s...
<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Risk value</th>
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<tbody>
<tr>
<td>Otorrhea</td>
<td></td>
</tr>
<tr>
<td>I: Dry</td>
<td>0</td>
</tr>
<tr>
<td>II: Occasionally wet</td>
<td>1</td>
</tr>
<tr>
<td>III: Persistently wet</td>
<td>2</td>
</tr>
<tr>
<td>IV: Wet, cleft palate</td>
<td>3</td>
</tr>
<tr>
<td>Perforation</td>
<td></td>
</tr>
<tr>
<td>Absent</td>
<td>0</td>
</tr>
<tr>
<td>Present</td>
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<tr>
<td>Cholesteatoma</td>
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<tr>
<td>O: M+I+S+</td>
<td>0</td>
</tr>
<tr>
<td>A: M+S+</td>
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</tr>
<tr>
<td>B: M+S-</td>
<td>2</td>
</tr>
<tr>
<td>C: M-S+</td>
<td>3</td>
</tr>
<tr>
<td>D: M-S-</td>
<td>4</td>
</tr>
<tr>
<td>E: Ossicle head fixation</td>
<td>2</td>
</tr>
<tr>
<td>F: Stapes fixation</td>
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<td>Middle ear: granulations or effusion</td>
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<td>1</td>
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<tr>
<td>Staged</td>
<td>1</td>
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<tr>
<td>Revision</td>
<td>2</td>
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</table>
Prognostic Factors

- Dornhoffer 2001, unsatisfied with the clinical correlation of the MERI, further analyzed clinical data.
- 200 ears, reconstructed with HAPEX PORP or TORP, were analyzed.
- Ossicular chain status, mucosal status, otorrhea, +/- mastoidectomy, and revision surgery were all significant prognosticators.
- Of note, presence of the stapes superstructure was not influential.
- Dornhoffer proposed the Ossicular Outcomes Parameters Staging (OOPS)
<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Risk value</th>
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<tbody>
<tr>
<td><strong>Middle ear factors</strong></td>
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<tr>
<td>Drainage</td>
<td></td>
</tr>
<tr>
<td>None</td>
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<tr>
<td>Present &gt;50% of time</td>
<td>1</td>
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<tr>
<td>Mucosa</td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>0</td>
</tr>
<tr>
<td>Fibrotic</td>
<td>2</td>
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<tr>
<td>Ossicles</td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>0</td>
</tr>
<tr>
<td>Malleus +</td>
<td>1</td>
</tr>
<tr>
<td>Malleus –</td>
<td>2</td>
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<tr>
<td><strong>Surgical factors</strong></td>
<td></td>
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<tr>
<td>Type of surgery</td>
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<td>No mastoidectomy</td>
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</tr>
<tr>
<td>Canal-wall-up mastoidectomy</td>
<td>1</td>
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<tr>
<td>Canal-wall-down mastoidectomy</td>
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<tr>
<td>Revision surgery</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>0</td>
</tr>
<tr>
<td>Yes</td>
<td>2</td>
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</tbody>
</table>
Prognostic Factors

- De Vos (2007) reported on 149 ears
- Multivariate statistical analysis identified the predictive value of the presence or absence of the malleus handle and the mucosal status of the middle ear mucosa in the prognosis of ossiculoplasties.
- They did not show predictive value in CWU mastoidectomy, otorrhea, myringitis, or length of the prosthesis.
- Best results were obtained in the Austin A (S+M+) and B (S-M+) classifications, with no difference between the two.
- This contrasts with previous thoughts on the importance of the stapes superstructure.
All three studies of prognostic factors identify middle ear mucosal status and presence of malleus handle as important predictors of successful hearing restoration.
With such a variety of options and materials available for reconstructing the ossicular chain, the otologic surgeon must consider using the method that provides the best hearing result with the least chance of complications.

The ideal study for comparison of techniques would be a single surgeon directly comparing techniques or materials on patients who had been risk stratified by a validated prognostic index, with reporting of complication rates and long-term follow up.

This study does not exist.

This talk will review studies published in the past decade in order to assist the otologic surgeon in making an informed decision about which technique to use.
Pasha (2000) studied 33 consecutive cases of OCR with HA PORP, TORP, or Kartush incus strut. Hearing results, based on postoperative mean ABG, were best when incus struts were used. Patients receiving incus struts had lower MERI scores in general, and, of course, had malleus handle present. 3 PORPs extruded; no incus struts or TORPs extruded. Cartilage caps were not placed over the prostheses.
Pasha

- A weakness of the study is that hearing results are not reported as percentage of patients closing ABG to within 20 dB.
- This study supports the use of the Kartush incus strut when both the handle of the malleus and the stapes superstructure are preserved.
House (2001) reported on a retrospective chart review of 1210 consecutive ossicular reconstructions with HA and Plastipore TORPs (n = 560) or PORPs (n = 650)

Closure of the ABG to within 20 dB was 63% (68% of PORPs, 58% of TORPs)

Hearing results were better for cases who had not had previous surgery, in those with a diagnosis other than chronic otitis media, when a cartilage graft was used, and for Plasti-Pore rather than hydroxylapatite.

Overall extrusion was 4%, with no difference between HA and Plastipore, but statistically lower when cartilage cap was used.
House’s study refutes claims that the stapes superstructure is unimportant to hearing results.

It also reinforces the importance of placing a cartilage cap between the prosthesis head and the tympanic membrane.
Iurato (2001) reviewed the literature at length to investigate hearing results from ossicular reconstruction in Austin-Kartush type A patients.

At 12 months minimum follow-up, success was shown to be 84% vs 82% for incus interposition vs allograft (ceramics or HA) PORP.

In addition, Iurato demonstrated that, on his own series of patients, success rate of homograft ossiculoplasty was 85% and hearing was stable over 3 years post-op.

Of note, Iurato reported no extrusions or displacements of his autografts.
Dalchow (2001) reviewed his experience with 1304 implanted titanium TORPs and PORPs. Considering all implants, he had a success rate of 76%. 0.9% implants extruded, 2% of implants were too short and had to be replaced, and 1.3% of implants became dislocated, for a total prosthesis related complication rate of 4.2%.
Ho (2003) reported on retrospective chart reviews on patients who had undergone ossiculoplasty using titanium middle ear implants.

- 64% and 45% of patients achieved air-bone gap less than 20 dB with PORP and TORP respectively.
- With the placement of cartilage graft interposed between the prosthesis and the tympanic membrane, no extrusions were observed.
Neff (2003) studied 18 patients who underwent tympano-ossiculoplasty with a titanium TORP.

- Hearing results showed 89% surgical success.
- The average follow-up time was 8 months (range, 2-21 months).
- The results compare favorably with his own results using a porous polyethylene TORP in which 67% had success.
- No extrusions/ displacements were seen in their short follow up time.
Rondini-Gilli

- Rondini-Gilli (2003) reported on 100 patients who received a HA PORP (n=65) or TORP (n=35).
- Extrusion or displacement of the implants occurred in 10% of cases.
- These displacements were more common when no cartilage cap was placed.
- The results were not reported as successful closure less than 20 dB ABG.
- In addition to an absent stapedial arch with type 3 tympanoplasty, a radical mastoidectomy and a previous tympanoplasty were related to poorer auditory results.
Hillman

- There was 1 extrusion in the titanium group. There was an additional single incidence of prosthesis failure in the titanium group.
- 60% of patients had a postoperative air-bone gap of 20 dB or less in the Plastipore group.
- In the titanium group, 45.3% achieved a 20 dB or less air-bone gap.

Successful rehabilitation of conductive hearing loss was obtained in 70% of PORPs and 44% of TORPs when titanium prostheses were used.

Comparison data revealed successful rehabilitation in 48% and 21% of non-titanium-based partial and total reconstructions, respectively.
Martin (2004) reported on a retrospective chart review of 68 ossicular procedures using a titanium TORP (n = 30) or PORP (n = 38). He obtained closure of the ABG to within 20 dB in 57% of cases. Hearing results were better for primary versus revision cases for PORPs versus TORPs and for intact canal wall (ICW) procedures versus canal wall-down (CWD) procedures. Extrusion rate was 1.5%. 
O’Reilly (2005) published a retrospective review of 137 patients (Austin-Kartush group A) demonstrating the effectiveness of incus interposition.

- 66.4% of patients had successful closure of the air-bone gap to within 20 dB. (mean 15.8 months post-op)

- There was no statistical correlation between MERI score and surgical success
Schmerber (2006) reported on a retrospective chart review of 111 patients implanted with either a titanium PORP or TORP. Success was obtained in the PORP group in 77% of the cases, versus 52% of the cases in the TORP group. 2 extrusions (1.8%) of the prostheses were observed at 17 and 20 months after surgery. Revision procedures for functional failure were carried out in 20 patients (18%). The major factors influencing good audiometric results were surgical procedures preserving the external auditory canal and the presence of the stapes.
Truy (2007) published a retrospective comparison of hydroxyapatite vs. titanium TORP and PORP.

- Success rate was 55% for HA TORP, 51% for TI TORP, 67% HA PORP, 72% TI PORP

- 10% of cases required revision for “prosthesis-attributed poor results”, including inadequate prosthesis length, extrusion due to poor cartilage cap, displacement, and poor hearing result

- Neither hearing results nor prosthesis related revisions were statistically significant between the two materials
Vassbotn (2007) published a retrospective study of procedures involving 73 titanium prostheses (38 PORPs and 35 TORPs).

Mean follow-up was 14 months.

Success was obtained in 77% of the patients, 89% for the Bell (PORP) prosthesis, and 63% for the Arial (TORP) prosthesis.

The overall extrusion rate was 5%.

The combination of CWD and TORP gave significant inferior hearing thresholds as compared to TORP/CWU and PORP/CWD combinations.
Siddiq (2007) prospectively assessed the early results of titanium partial and total ossicular replacement prostheses in chronic ear disease.

33 consecutive patients (20 PORPs and 13 TORPs) were analyzed.

PORP (85%) had a higher success rate than TORP (46%).

There were no cases of extrusion.
De Vos (2007) reported on 149 ears all implanted with titanium PORPs and TORPs. Success rate was 60% with no difference between PORP and TORP. Prosthesis extrusions occurred in 3.5% of patients and displacement of the prosthesis occurred in 4.3%.
Emir (2008) reviewed 304 patients who underwent ossiculoplasty with intact canal wall.

- Autologous incus interposition resulted in 58% success rate, whereas plastipore PORPs resulted in 56% success rate.
- 9.3% of implants extruded.
Coffey

- Coffey (2008) reviewed 105 cases, including 80 performed with titanium and 25 with nontitanium implants.
- Success was achieved in 50.0% of nontitanium cases and 77.1% of titanium cases.
- Extrusion was observed with two nontitanium prostheses (8.0%) and three titanium prostheses (3.8%).
Neudert (2009) compared titanium prostheses to incus interposition by studying 18 cadaveric temporal bones and 66 patients.

Though, using Laser Doppler vibrometry, they demonstrated superior transmission in the titanium PORPs, this superiority was not present in vivo.

There was no significant difference in surgical success (66%) between patients implanted with titanium PORPs vs those who underwent incus interposition.
<table>
<thead>
<tr>
<th></th>
<th>POR Interposition</th>
<th>Titanium PORP</th>
<th>Non-titanium PORP</th>
<th>Titanium TORP</th>
<th>Non-titanium TORP</th>
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<tr>
<td>Pasha (2000)</td>
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<td>House (2001)</td>
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<td>Schmerber (2006)</td>
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<td>Truy (2007)</td>
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<td>72%</td>
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## Success Rates

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<td>Vassbotn (2007)</td>
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<td>Coffey (2008)</td>
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<td>Emir (2008)</td>
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<td>Mean</td>
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Conclusions

- A standardized prognostic classification must be adopted in order to compare future results across multiple studies.
- A cartilage cap must be used when an allograft PORP or TORP is used.
- Extrusion/displacement rates of allograft prostheses are between 0.5-10% and are lower when a cartilage cap is used.
Conclusions

- Across the past 10 years of published reports, based on anecdotal data, titanium PORP yields approximately equivalent hearing results to incus interposition.
- TORP reconstruction most probably yields a poorer hearing result than PORP when all cases are considered.
- Considering the technical skill needed to successfully perform incus interposition, a general otolaryngologist should opt for titanium reconstruction prosthesis for OCR.
References

- Emir H. Ossiculoplasty with intact stapes: analysis of hearing results according to the middle ear risk. 2008 Dec 31:1-7
References

- Schmerber S. Hearing results with the titanium ossicular replacement prostheses. Eur Arch Otorhinolaryngol. 2006 Apr;263(4):347-54.