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REVIEW

# Bridging the Incudo-stapedial Gap: State of the Art

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**Objective**: Isolated defect of the incudo-stapedial articulation is the most commonly encountered ossicular defect during middle ear surgery. We classified this defect into 4 types according to the length of defect in the long process of incus. We recommended several choices for reconstruction of each type. We arranged our choices respectively, where the first choice is highly recommended whenever applicable. The management for each type is based on our forty years of experience in ossiculoplasty and on reviewing recent literature.

**Setting:** Tertiary Care Center.

**Patients:** We included patients in whom an isolated incudo-stapedial defect was identified intraoperatively.

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## Introduction

Isolated defect of the incudo-stapedial articulation, with otherwise intact ossicular chain, is the most commonly encountered ossicular defect during middle ear surgery. It is commonly the result of bony erosion of the distal part of the long process of incus as a pathological consequence of chronic otitis media. However, Incudo-stapedial defect can result from head trauma, can be iatrogenic, where it occurs accidentally, induced intentionally to guard against excess manipulation of the stapes, or occurs in the late postoperative period as in case of post-stapedectomy incus necrosis. Incudo-stapedialdefect can also be congenital where it is considered the second most common congenital isolated ossicular anomalies after stapes fixation. [1,2,3]

Confirming the diagnosis of isolated incudo-stapedial defect is only done intraoperatively. However, several preoperative diagnostic tools can help the oto-surgeon to predict the presence of such defect and to be ready to manage it. These tools include, pure tone audiometry (large air-bone gap), tympanometry (hypermobile ossicular chain and absent stapedial reflexes), Otoendoscopy (where angled endoscope can pass a large tympanic membrane perforation), and CT petrous bone, including recently applied virtual CT otoendocopy. [4,5]

Various ossicular reconstructive techniques have been reported, however, a survey has showed that ossiculoplasty is not a common procedure among otolaryngology surgeons. Limitations to perform ossiculoplasty are related to unavailability of a reliable reconstructive material, unpredictable results, expensive implants, low prediction of possible ossicular chain defect, and lack of standardized techniques for different ossicular chain defects. [6]

The most commonly used technique for reconstruction of incudo-stapedial defects, whatever its degree, is still the traditional incus transposition or interposition. Whenever the autologous incus is unusable, preserved homologous incus is another valid option. Incus inactivation-preservation protocols including immersion in 70% Alcohol, in Cialit (sodium-2-ethyl-mercuri-mercapto-benzoxazole-5-carboxylate), in buffered 4% formaldehyde, and NaOH-autoclaving protocol. [7, 8]

It is particularly frustrating for the otologic surgeon to completely change the anatomical arrangement of the ossicular chain when there is only a limited necrosis of the long process of the incus. Early techniques like wedging a piece of bone or cartilage between the residual incus and stapes capitulum had an appealing simplicity, however, when the gap is wide, this reconstructive technique is typically associated with disappointing hearing results and eventual displacement of the wedge. [9,10]

Despite refinements in materials and prosthesis design,

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there are only few ossicular prostheses that can approximate the acoustic efficiency of the normal ossicular chain in case of isolated erosion of the long process of incus. These include Applebaumincudo-stapedial joint prosthesis (Gyrus ENT, Bartlett, Tenn), a rectangular piece of dense 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. It is presented in 2 sizes, small and large, according to the length of the rectangle, either 2 mm or 2.5 mm. This prosthesis although functionally efficient and relatively easy to apply, the extrusion rate is still considerable. [11,12]

Another option is Kurz angular prosthesis (Kurz Medical, Inc, Norcross, Ga) made of a gold shaft, gold cup, and titanium clips. The prosthesis although allows a largely physiological reconstruction of the chain, coupling to the long process of the incus is not always easy. The relatively rigid titanium clips are not often be fixed securely when the process of the incus is short. When clipping, strain of the annular ligament by tilting of the stapes should be watched for. In addition this type of prosthesis is relatively expensive. [13,14]

Rebuilding the eroded incus in situ using a biocompatible bone like materials was a smart idea that ensures resembling the original anatomy of the ossicular chain and avoids undesirable manipulations. Several materials have been used to bridge the gap including glass ionomer cement, hydroxyapetite cement, and tissue adhesive materials (eg. n-butyl cyanoacrylate) either alone or mixed with bone pate. [9,15,16,17]

Glass ionomer cement has several favorable criteria that make it an important reconstructive option of such defect. These criteria includes its high biocompatibility, strong chemical adhesion to bone, mouldability on placement, bioconductive/osteoconductive ion release, minimal shrinkage on setting, ease to trim when set, and relatively economic price. From the functional standpoint of view, several studies have showed that is gives a satisfactory, long standing hearing results.[18,19,20,21]

**Classification of incudo-stapedial defects**

The average length of the normal long process of incus is 3.2 mm. We classified the isolated incudo-stapedial defect into 4 types according to the length of defected long process of incus which is measured intraoperatively (from the center of head of stapes to the tip of long process of incus) either using a micro-ruler, or right angle micro-hooks with standard lengths (1 and 2 mm). In type 1, there is disarticulation of the incudo-stapedial joint without evident erosion of the lenticular process of incus. In type 2, there is erosion of long process of incus of less than 1 mm. In type 3, there is erosion of long process of incus of 1 – 2 mm. In type 4, there is erosion of long process of incus of more than 2 mm. (Fig. 1)

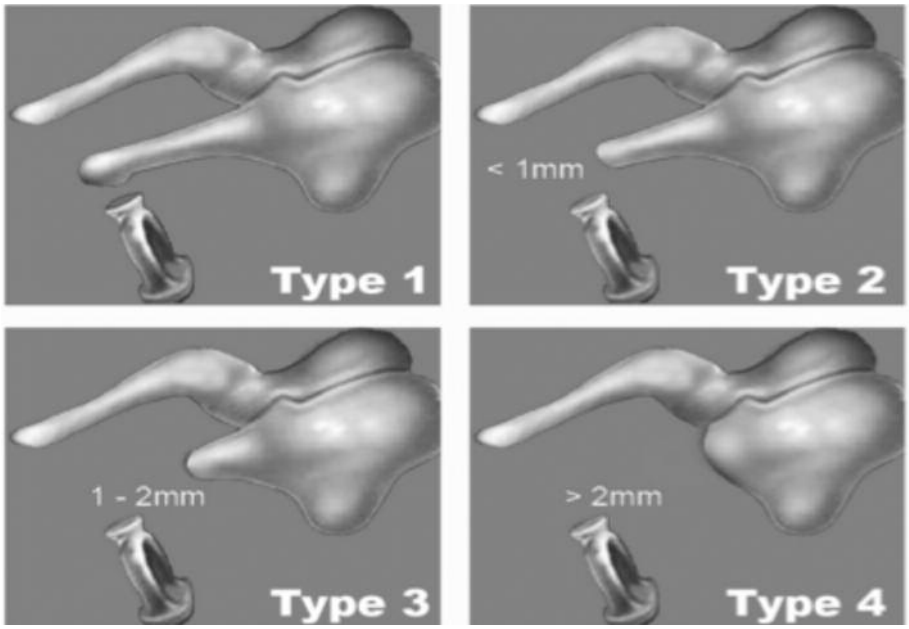


**Figure 1.** Classification of Incudo-stapedial Defects.

**Table 1.** Recommended reconstructive modalities for each type of incudo-stapedial defects

| | **Recommended Reconstructive Modality** | | | |
|---|---|---|---|---|
| **I-S Defect** | ***1st choice*** | ***2nd choice*** | ***3rd choice*** | ***4th choice*** |
| ***Type 1*** | GIC bridging | Cartilage interposition | __ | __ |
| ***Type 2*** | GIC bridging | Applebaum prosthesis | Autologous Incus transposition | __ |
| ***Type 3*** | GIC bridging | Autologous Incus transposition | Incusreplacement prosthesis / PORP | Homologous Incus transposition |
| ***Type 4*** | Autologous Incus transposition | Incusreplacement prosthesis / PORP | Homologous Incus transposition | __ |

In type 1, the lenticular process is preserved and is usually aligned with the head of the stapes. This is particularly encountered in post-traumatic cases either accidental or iatrogenic. It is easy to fix both bones together using a minute amount of glass ionomer cement. This will highly resemble the normal anatomy and provide a long-term and a mechanically stable connection without the hazards of incus removal and changing the mechanical arrangement of the ossicular chain.

### Technique of Glass Ionomer Cement Bridging

We use KetecCem® (ESPE, Germany), glass ionomer cement (glass polymaleinate cement). It is supplied in as a powder bottle which contains aluminum fluorosilicate powder, and a liquid bottle which contains maleic acid liquid. The working set supplied by the manufacturer includes a spoon and a mixing pad.

The incudo-stapedial region is well exposed. The mucosa is meticulously denuded off the involved ossicular surfaces with needle or hook. Every effort is done to make the field as dry as possible during the reconstruction. A suitable piece of dry gel foam is placed medial to the working area to prevent any undesired contact between the cement and the surrounding tissues. The glass ionomer cement is then prepared by mixing a spoon of powder with a single drop of acid liquid over a sterile pad until a homologous sticky paste is formed.

With a blunt curved needle, a minute drop of the soft GIC is picked up and gently spanned between the long process of incus and the head of stapes. Any excess cement can be easily removed using a suction tip. After complete setting of the cement, which takes from 7 to 10 minutes, the gel foam is removed gently. The movement of the ossicular chain is checked, to make sure that there is satisfactory mechanical transmition between the malleus and stapes footplate (Fig. 2).

Before utilizing glass ionomer cementwe used to interpose a rectangular piece of cartilage between both ossicles. We made a hole in the center of the graft to receive the lenticular process and the capitulum of stapes. Tragal or conchal autologous cartilage graft is used according to the approach. When cartilage is mechanically stable, satisfactory hearing results are

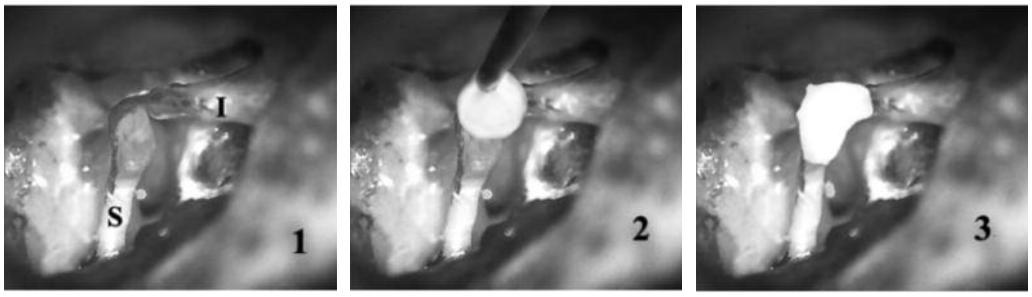


**Figure 2.** Bridging of a type 2 incudo-stapedial defect of the left ear using GIC. **1:** eroded lenticular process of incus. **2:** cement is spanned between the long process of incus (I) and head of stapes (S). **3:** the reconstructed connection after hardening of cement.

usually achieved. We now recommend the use of this option only if glass ionomer cementisnot available. (Fig. 3)

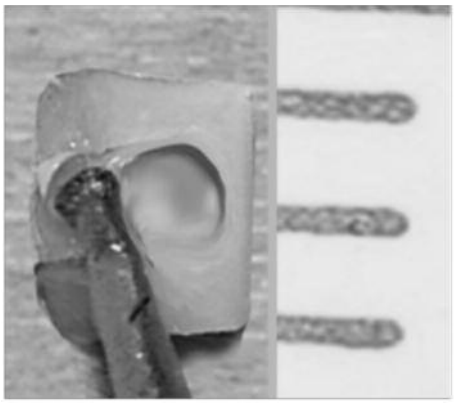

**Figure 3.** A rectangular block of cartilage graft measuring 2 2 mm is stripped from its covering perichondrium. A hole is created in the center of the block using a diamond bur. This block is interposed between lenticular process of incus and head of stapes.

In type 2, when the lenticular process is missing and the gap is less than 1 mm, bridging this gap with glass ionomer cement is the reconstructive modality of choice. Applebaum joint prosthesis comes as a second reliable option.This prosthesis contains a trough that accepts the remaining incus long process remnant and a hole that accommodates the stapes capitulum.

**Technique of Applebaum prosthesis insertion**

The appropriate size (small or large) is determined according to the defect. The small prosthesis is generally sufficient for most defects, and the large prosthesis is needed for bigger defects. The implant is manipulated using a needle and a suction tip where the grooved portion is slided under the long process of the incus, and the hole is placed over the head of the stapes. The head of the stapes is visualized through the hole that runs through the prosthesis, in order to assure proper positioning of the implant. The prosthesis is self-supporting if it is positioned properly. The malleus is palpated to verify good motion transmission the prosthesis to the stapes. We recommend placement of cartilage graft lateral to the prosthesis to guard against extrusion. (Fig. 4)

If both previous options are not available, a third option will be the transposition of the modeled autologous incus between the head of stapes and the handle of malleus. The audiological results are less predictable than those of the first two choices due to the possible bony fixation of the incus to the surrounding bony walls.

**Technique of incus removal, modeling and transposition**

The long process of incus is pulled laterally with a small hook to dislocate the incudo-mallear joint and to lateralize the long process. A right angled hook is inserted between the malleus and long process of incus to reach the incudo-mallear joint which is completely detached by anterior to posterior rotation of the hook.The long process of incus is grasped carefully with a forceps, pulled inferiorly toward the hypotympanum, and then taken out.

The body of incus is firmly held using the ossicle holding forceps.The surface of incus is meticulously polished from any soft tissue remnant using a 0.8 mm diamond burr with continuous irrigation.The superior border of the body is fattened using a 1 mm cutting burr, to favour its attachment to the TM. The articular face of the body is flattened using a 1 mm cutting burr, to avoid its contact the posterior bony wall.The long process is removed completely then a hole is created in its stump using a 0.8 mm cutting burr. The hole is further deepened using a 0.6 mm cutting burr to make it deep enough to receive the head of stapes. A small wedge is removed from the back of the socket to receive the tendon of stapedius.A small groove is made on the superior border of the short process using a 0.8 mm cutting burr to accommodate the handle of malleus.

The molded incus is introduced into the tympanic cavity using a fine suction tip. With a small hook, the head of stapes is introduced into the hole with the short process directed inferiorly, then the manubrium and its underlying graft is pulled laterally and the short process of incus is gently twisted and slid under the manubrium.Gelfoam is placed all around the interposed incus to support it and to avoid fixation to the posterior wall. (Fig. 5)

If the handle of the malleus is not in alignment with the head of stapes, either we do malleus handle relocation. The tendon of the tensor tympani is cut with 90˚ hook then the handle of malleus is pulled backwards by the hook to align it with the head of the stapes. This makes transposition of the incus between the handle of malleus and the head of the stapes easier. Or we directly interpose the autologous incus between the head of the stapes and the ear drum (Fig. 6)

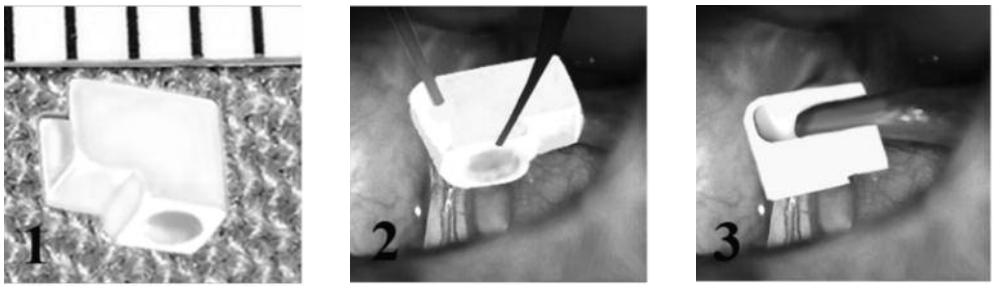


**Figure 4.** Application of Applebaum prosthesis. **1:** prosthesis design. **2:** prosthesis introduced into the working area using a needle and a suction tip. **3:** prosthesis in place.

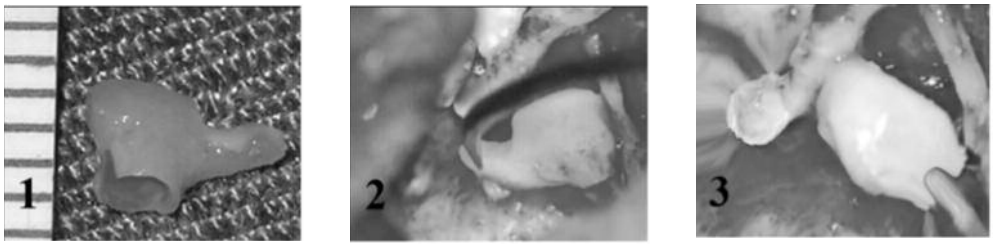


**Figure 5.** Incus transposition in the left ear. **1:** modeled autologous incus. **2:** the acetabulum is positioned over the head of stapes, the manubrium is pulled laterally and the short process is twisted medial to it. **3:** interposed incus in place.

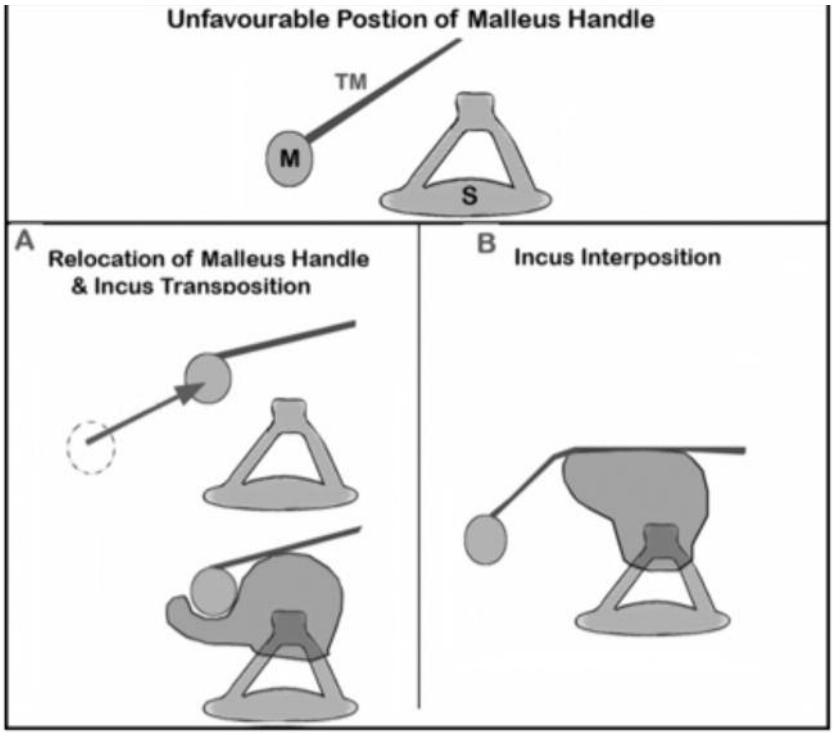


**Figure 6.** When the handle of the malleus (M) is not in alignment with the head of stapes (S), either we do malleus handle relocation to make the transposition of the incus between the handle of malleus and the head of the stapes easier **(A),** or we interpose the modeled incus between the head of the stapes and the ear drum **(B)**.

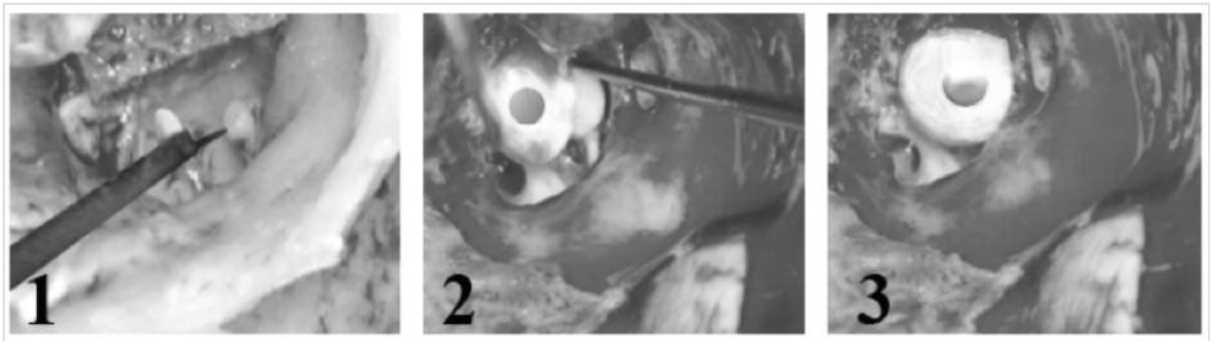


**Figure 7.** Placement of PORP.**1:** Measuring the distance between head of stapes and bony annulus. **2:** placement of PORP over the head of stapes. **3:** PORP in place.

In type 3, with a gap of 1 - 2 mm, still the glass ionomer cement is the modality of choice. A second option will be autologous incus transposition. Occasionally when the incus is unusable, apartial ossicular replacement prosthesis (PORP) can be used. Transposition of a modeled homologous incus comes as a fourth option. NaOH-autoclaving protocol is a reliable method of inactivation and preservation of homograft ossicles. [8] In this protocol the ossicles are immersed in NaOH for 1 hour followed by packing, and autoclaving at 134°C for 8 minutes.

**Technique of PORP placement**

We prefer using Richards centered PORP prosthesis (Gyrus ENT, TN, US), which is formed of a Hydroxylapatite head and HAPEX Shaft. The shaft of this PORP is cannulated to facilitate visualization of the head of stapes during insertion.

The distance between the head of stapes and the bony annulus is measured using a Paparella-type micro-ruler. Any extra-length of the PORP is cut using a sharp blade over a wooden tongue depressor.

The PORP is introduced into the middle ear using a microforceps. Using a small hook and suction tip, the PORP is positioned so that the cannulated shaft is well fitting around the head of stapes. The mechanical stability of the PORP is assessed. Gelfoam is placed all-around the PORP for further support and to keep it away from the bony walls. Cartilage graft is placed lateral to the head of PORP either in contact with the malleus handle (if in alignment with the head of the stapes) or in direct contact with the ear drum (if the handle of malleus is not aligned). (Fig. 7).

In type 4, with a larger gap of more than 2 mm, autologous incus transposition is usually the modality of choice. However, if incus is unusable for any reason a PORP would be used. Transposition of a modeled incus homograft comes as a third option.

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