Motion of the Human Tympanic Membrane and Stapes Velocity after Placement of a Total Ossicular Replacement Prosthesis with Cartilage Cover.

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Introduction
Reconstruction of the ossicular chain is required in 40-90% of all tympanoplasties, making ossiculoplasty a frequently performed operation; however, the results of such reconstructions vary greatly. Causes of the variability in hearing results include imperfect hearing results include imperfect placement of the prosthesis, improper choice of materials, and failure to correct the underlying disease. Failure of the ossicular chain reconstruction is associated with profound hearing loss, which is caused by the TM or inner ear, or lack of aeration of the middle-ear spaces. A common form of TM reconstruction is the use of an ossicular replacement prosthesis in conjunction with a sheet of cartilage to reduce the chance of the prosthesis extruding through the tympanic membrane (TM). A major mechanical factor in ossicular reconstructions is the tension produced by the prosthesis, which affects the stiffness of the annular ligament of the footplate and the TM, and the coupling of TM motions to the stapes. This tension changes along the length of the ossicular replacement prosthesis.

In this study, we investigated how the forces of different lengths, and different tensions, affect both TM and stapes footplate motion in ossicular reconstructions. The method involved the use of a cartilage prosthesis between the TM and the stapes footplate. The prosthesis was designed to reduce the tension produced by the prosthesis on the TM and stapes footplate.

Methodology
Temporal Bone (TB) Preparation and Configuration
Four human temporal bones without history of otologic disease were used. TBs were obtained at autopsy within 24 hours of death at the University of Pittsburgh Medical School. The TM was removed from each bone and was stored in a saline solution containing antibiotics. The bone was then fixed in 10% formalin for 48 hours before use. The bone was then dissected into the ossicular chain, which includes the incus, malleus, and stapes.

Results
Stroboscopic holography was used to quantify the magnitude and angle of the displacement of over 400,000 locations on the surface of the tympanic membrane at 0.5, 1, 4 and 8 kHz. At 1 kHz and below, the entire TM surface moves nearly in-phase (shown in hologram results as slowly varying phase gradients of less than 1/4 cycle over the TM surface) with one or two local displacement magnitude maxima. At 4 and 8 kHz, the TM surface motions are more complex. Rings of multiple displacement magnitude maxima and minima are arranged around the manubrium. These multiple magnitude extrema are associated with small but consistent phase variations that are also arrayed across the TM surface. Removal of the incus produced an increase in the TM displacements at low frequency, consistent with removal of cochlear load.

Conclusions
Preliminary results indicate:

- Reconstruction length and the size of the cartilaginous disk differentially affect the mobility of the TM and the stapes. However, there is significant variation in the acoustic response of similarly reconstructed ears, even in this relatively well-controlled preparation.

The data suggest an advantage to 'Best Fit' TORPS with a 'Small Cartilage' cover that does not exceed the area of the pedestal that interfaces with the TM.

References

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