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ORIGINAL ARTICLE

Effect of Interfaced Cartilage Size in Malleus-Stapes Assembly Using Allograft: Experimental Study

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Objective: To investigate the effect of the interfaced cartilage size on eardrum vibration, by performing malleus-stapes assembly using partial ossicular replacement prosthesis in the middle ear of rabbits.

Materials & Methods: Four New Zealand white rabbits were anesthetized. Canal wall-up mastoidectomy, with wide opening of the facial recess, was performed. During malleus-stapes assembly, a piece of cartilage was interfaced between partial ossicular replacement prosthesis head and manubrium. The diameter of the interfaced cartilage was 3 mm (equal in area to its head) and 2 mm (two-thirds the area of the head). The velocity of the umbo was measured by single point laser Doppler vibrometer.

Results: At low frequencies (<2 kHz), the small cartilage (2 mm) produced better displacement with statistical significance ($p<0.05$). The large (3 mm) cartilage produced reductions in displacement.

Conclusion: A small-sized interfaced cartilage in malleus-stapes assembly yields better low frequency results.

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Introduction

Hearing improvement after ossicular reconstruction for chronic otitis media is challenging to achieve. Variables that influence success include management of the mastoid, treatment of the canal wall, extent of mucosal disease, type of ossicular reconstruction, and type of material in the ossicular prostheses. The most commonly encountered defect of the ossicular chain is a discontinuity in the presence of an intact malleus and an intact mobile stapes. There are two primary methods available to reconstruct the incus defect: either by columella effect to tympanic membrane or by malleus-stapes assembly (MSA) between stapes capitulum and malleus. The choice lies between using autologous tissue or some form of synthetic ossicular prosthesis. When the autologous incus cannot be used, it is the surgeon's preference to use MSA. Many prostheses have been used to bridge the gap between stapes capitulum and malleus. Polycel is a thermal-fused high-density polyethylene sponge, which permits coupling with other materials, such as stainless steel; thus, lending itself to a wide variety of prosthetic designs [1-3]. Although hydroxyapatite is commonly used for MSA, Polycel is easy to trim the length of the shaft, compared to hydroxyapatite. Moreover, it is easy to remove during revision ossiculoplasty. However, hydroxyapatite PORP cannot be removed easily during revision ossiculoplasty in the case of recurrent cholesteatoma.

Displacement or lateralization with possible extrusion and perforation are potential problems, following

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ossiculoplasty, especially if the prosthesis sits in direct contact with the tympanic membrane. Grote [4] reports an extrusion rate of 4%, using incus/stapes prostheses when the prosthesis was used as a columella. He also mentioned that extrusion did not occur when the prosthesis was interposed between the footplate and the handle of the malleus. Although PORP that sits under the malleus handle can maintain a separation between the tympanic membrane and the prosthesis, the edge of the head may come in contact with the tympanic membrane, directly, in the case of Eustachian tube dysfunction [5]. Sliced cartilage interface, between the prosthesis and the manubrium of the malleus, is often used during MSA or malleus footplate assembly [6-7]. The size of the cartilage cover is one of the few variables over which a surgeon has control during an ossiculoplasty. There have been only eight English literatures regarding ossicular reconstruction, using laser Doppler vibrometer in the Medline search [8-14].

To date, there are no studies have investigated the acoustics of interfaced cartilage between the hand of malleus and head of ossicular prosthesis. In, Confucianism hinders the use of human cadaveric fresh temporal bone. Instead, rabbit temporal bone has been widely used for surgical and experimental approaches [15-16]. We have used interfaced cartilage between the handle of malleus and ossicular prosthesis during MSA. The objective of this study is to investigate the effect of the interfaced cartilage size on tympano-ossicular vibration by MSA, using PORP in the middle ear of rabbits.

Materials and Methods

All experiments were performed in accordance with the local ethical committee at for Resistant Cells, . Four New Zealand white rabbits (male, 2.5 kg, 2-years-of-age) were anesthetized, using intramuscular Rompun (2 mg/kg) and Zoletil (Tiletamine/Zolazepam 1.5 mg/kg), and subsequently sacrificed by decapitation. The head, including tympanomastoid parts of the petrosal bones, were dissected. Canal wall-up mastoidectomy with wide opening of the facial recess was performed, using a large cutting bur and suction-irrigation (Fig. 1A,B). The implants used for the surgical procedures were constructed of Polycel partial ossicular replacement prosthesis (Austin; PORP), which consisted of a round and flattened head with a centrally placed and elongated hollow shaft. The interfaced cartilage was taken from the concha cartilage. An interface by a piece of cartilage between the manubrium and the head of the PORP was performed. The diameter of the interfaced cartilage was 3 mm (equal in area to its head) and 2 mm (two-thirds the area of the head) (Fig. 2A,B,C). The cartilage was 0.5 mm in thickness.

The velocity of the manubrium of the tympanic membrane was measured due to prominent stapes tendon and facial nerve, which hides the footplate of the stapes. Stimuli were frequency sweeps from 0.1–10 kHz at a 90-dB sound presentation level (SPL). An earphone of a TDT workstation (ABR/OAE Workstation; Tucker-Davis Technologies,) was the sound source; the earphone was placed within 2–3 mm of the eardrum, through one of the two available openings of a specially designed sound coupler. The ear canal pressures were measured with an ER-7C microphone (Etymotic Research,) with the probe tube situated 2 mm from the tympanic membrane through the opening of the sound coupler. The outer surface of the speculum was covered by a glass cover slip. The velocity

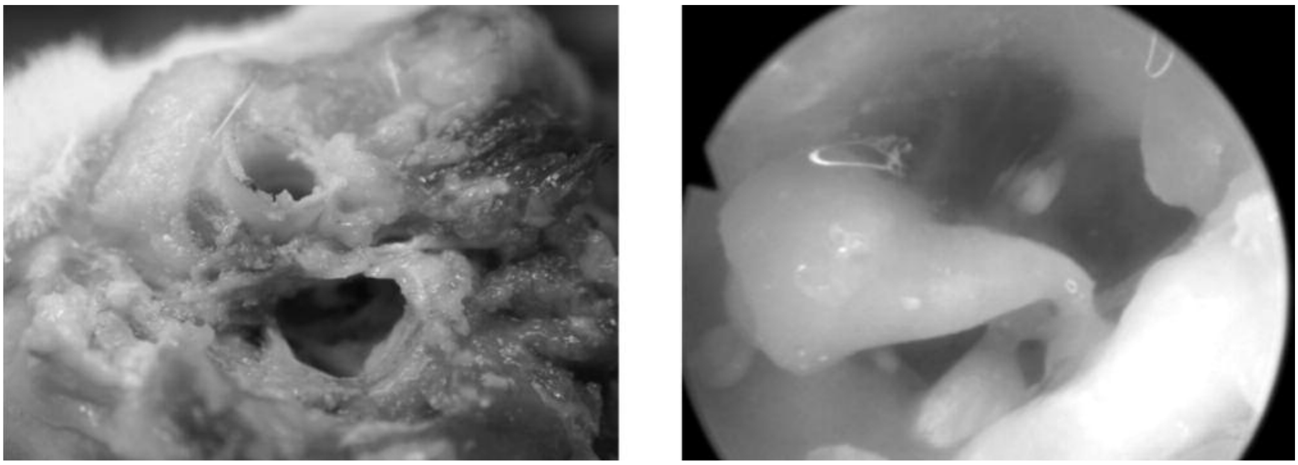
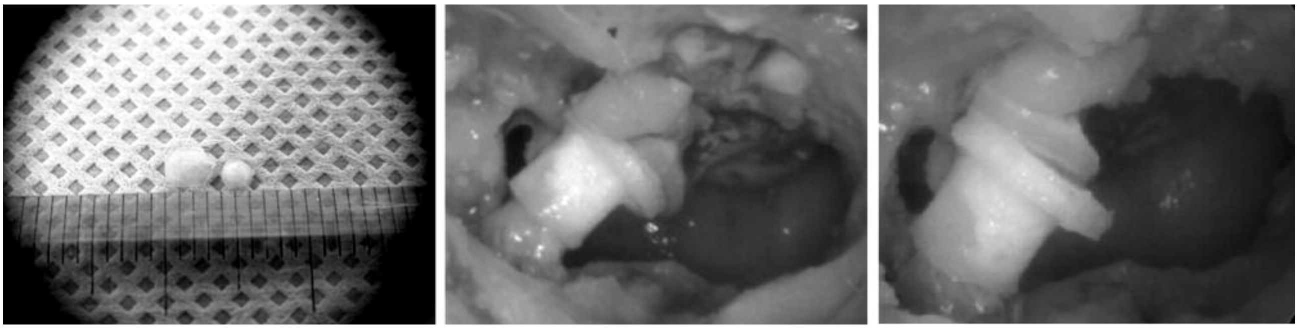


Figure 1. Canal wall-up mastoidectomy and posterior tympanotomy **(A).** Magnificed view of ossicular structure via posterior tympanotomy. The obturator foramen and footplate is not seen by dehiscent facial nerve . Malleus and incus are fused in rabbit **(B).**



A) B) C)

Figure 2. Interfaced cartilage taken from the concha cartilage **(A).** Between the manubrium and head of the PORP was interfaced by a piece of cartilage. Austin PORP (Polycel), L=2.5, HD=2.5, SID=1.17 mm, PORP: partial ossicular replacement prosthesis, HD: head diameter, SID: shaft inner diameter. The diameter of the interfaced cartilage was 3 mm (equal in area to its head, **B)** and 2 mm (two third in area to its head, **C).**

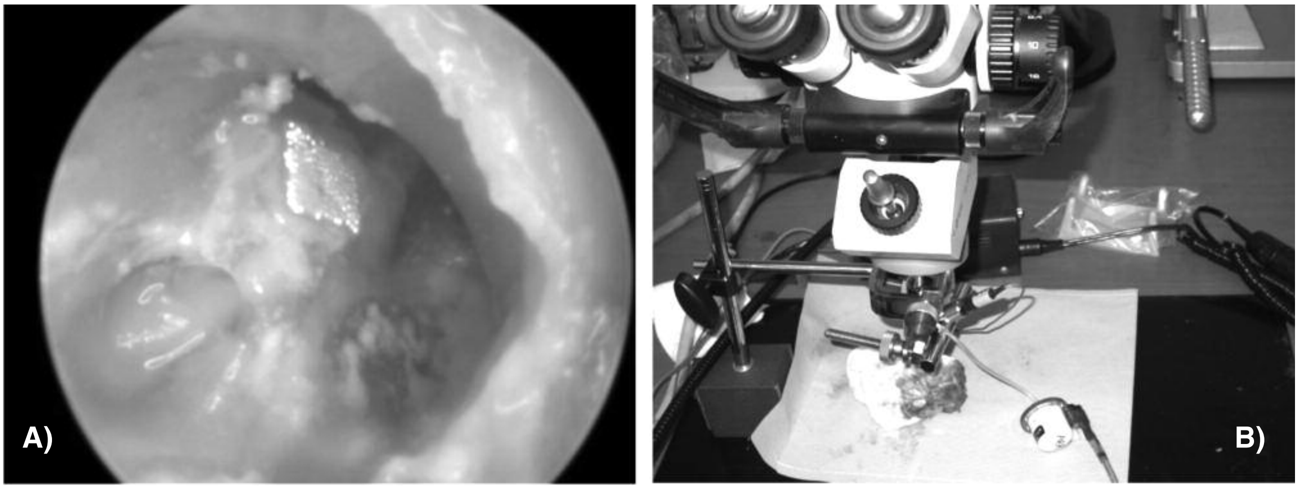
of the tympanic membrane over the interfaced cartilage was measured with a laser Doppler vibrometer (LDV) (CLV-700 sensor head, HLV-1000 vibrometer controller; Polytec,). The LDV was mounted onto a Leica microscope and was used to focus a helium-neon laser onto the center of the handle of the malleus. The targets were 0.5 mm^2 of foil with reflective polystyrene microbeads, weighing <0.05 mg (3M,). The output voltages of the vibrometer and the microphone were analyzed, using SigCal Fast Fourier Transform analyzer software (Tucker-Davis Technologies) (Fig 3). The Mann-Whitney U test was performed for statistical analysis. If the p value was <0.05, statistical significance was concluded.

Results

Above 2 kHz, manubrium vibration showed a similar displacement. However, at low frequencies (<2 kHz), the small cartilage (2 mm) produced better displacement with statistical significance ($p<0.05$). The large (3 mm) cartilage produced reductions in displacement (Fig. 4).

Discussion

The present study measured the vibration of the handle of the malleus after MSA, using PORP with interfaced cartilage using rabbit temporal bone. The ossicular chain of the rabbit is very fragile and can be destroyed by even minimal manipulation. The transection of the incudostapedial joint was performed using a fine needle



A) B)

Figure 3. Reflection tape of the tympanic membrane over the manubrium **(A).** The velocity of the manubrium of the tympanic membrane over the interfaced cartilage was measured with a laser Doppler vibrometer (LDV) **(B).**

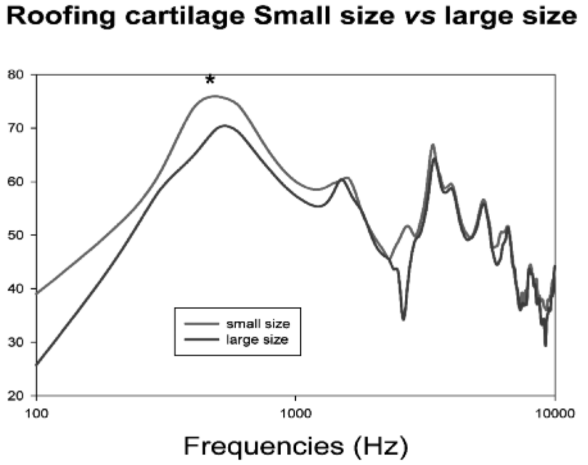


Figure 4. At low frequencies (<2 kHz), the small cartilage (2 mm) produced better displacement with statistical significance ($p<0.05$; denoted by *).

electrocutter. Huber et al [17] investigated the vibration pattern of the tympanic membrane using laser scanning vibrometer after placement of total ossicular replacement prosthesis (TORP). They placed a TORP between the posterior superior quadrant and the stapes footplate. The area of the posterior superior quadrant that moved the most in normal temporal bone moved about the same extent as the umbo over all frequencies, following the placement of the TORP. Over the measured frequency range, the tympanic membrane lying on the TORP moved in phase and at the same amplitude as the TORP itself and the umbo. In this study, we measured the umbo displacement lying on the PORP. Morris et al [12] measured the stapes center vibrations for PORP ossiculoplasty with tympanic membrane stapes assembly, instead of MSA. They covered the PORP by a piece of cartilage having four different diameters: larger (twice that of its head), medium (equal to the head diameter), small (one-third to one-half the head diameter), and very small (under one-third the head diameter). The small and very small cartilages produced similar results, and both performed better than the tympanic membrane assembled to stapes head without interfaced cartilage. But, the large cartilage cover performed the worst in low frequencies. In the present study, the stapes was not accessible for measurement because of the prominent facial nerve. In MSA, we compared the two different sized interfaced cartilages. Significant effects on the transmission of vibrations were evident depending on the interfaced cartilage cover size. Small-sized cartilage, whose diameter was two-thirds of the head, yielded a better result than the medium-sized cartilage that was equal in diameter to the head at lower frequencies. Although large-sized interfaced cartilage yielded poor low frequency results, when Eustachian tube function is poor, the interfaced cartilage size should be increased; because the edge of the head of PORP can be in contact with the tympanic membrane directly in MSA. The present experiment was performed with the normal tympanic membrane and Eustachian tube function. In conclusion, a small-sized interfaced cartilage yields better low frequency results.

Acknowledgements

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