Vibration Characteristics of Grafts for the Tympanic Membrane

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ABSTRACT

Perforation of the tympanic membrane occurs frequently as a result of infection, external trauma, and high-level impulsive sound pressure, such as that associated with an explosion. Many different surgical techniques can be used to repair the tympanic membrane and ossicles. Clinical operations such as tympanoplasty are undertaken to repair the damaged tympanic membrane and ossicles, thus improving hearing and reducing the chance of infection. The membrane is repaired or replaced with the use of graft materials, either from the patient’s body or from artificial sources. The selection of graft material is very important because, as much as possible, it must exhibit the same dynamic behavior as the natural membrane. To compare various allograft materials, investigators developed a model of the ear on which different graft materials can be replaced. Three different membrane materials—irradiated allograft dura (Tutoplast® Dura; IOP Inc., Costa Mesa, Calif), irradiated allograft fascia lata (Tutoplast Fascia Lata; IOP Inc.), and irradiated allograft fascia temporalis (Tutoplast Fascia Temporalis; IOP Inc.)—were used. Vibration responses of these membrane materials produced by defined sound signals with different frequencies were recorded by a small strain gauge; the spectra of sound for various corresponding input signals were recorded, and the results were compared with those of the sample graft material. Tutoplast Fascia Lata accomplished the best dynamic performance in vitro. Additional clinical and experimental data are needed, however, to determine which of these materials provides the best audiological and clinical performance.
Keywords: grafting materials; tympanoplasty; allografts

INTRODUCTION

Tympanoplasty is a surgical procedure that is performed to eradicate an infectious process in the middle ear cavity and to restore hearing. Different techniques have been devised for tympanoplasty; each case should be evaluated individually so the best approach can be determined.

The complex structure of the human ear is sensitive to sound frequencies between 20 Hz and 20 kHz. The whole system, along with sound reception, is a perfect frequency analyzer. Physiologically, hearing is the result of transmission of sound-induced vibrations to the fluids within the inner ear, peripheral analysis of these vibrations (low frequency in the apical segment, and high frequency in the basal segment of the cochlea), and conversion of mechanical energy to electrical signals within the inner ear.

To restore the sound transformation function of the middle ear to inner ear fluids, a connection must be made between the intact tympanic membrane and the inner ear. Tympanic membrane perforations cause hearing loss by reducing the sound pressure difference between the external ear and the middle ear; this results in decreased ossicular coupling. Perforations may also cause recurrent infection in the middle ear, which may worsen ossicular function and inner ear capacity.

Many techniques have been devised to repair a perforated membrane, and numerous materials have been used for grafting the eardrum. It is important for the graft material to respond to acoustic energy in a manner similar to that of the original tympanic membrane. For human patients, the substitute should best respond to the frequency range of normal daily speech.

The most common preferred material is the temporal fascia, which was introduced in the early 1960s. Dura, cartilage, vein walls, normal skin, perichondrium, and fat may also be used for this purpose. With advancements in the technology of processing and storing cadaver materials, allogenic materials are being used more frequently and, as with autografts, are available in a variety of types. Cadaver substitutes are nourished by the body after implantation, leading to new tissue formation. Because of donor site morbidity, additional incision and operating time, and lack of suitable tissue for revision, allograft materials may be used as an alternative in tympanoplasty. Tutoplast® (IOP Inc., Costa Mesa, Calif) is an allograft material that is applied through a tissue graft cleaning and preservation process in which solvent dehydration is used to virtually eliminate the possibility of disease transmission without compromising its biological or mechanical properties. Tutoplast has been commercially available for longer than 30 y and has been used in many surgical disciplines, including dentistry, neurosurgery, orthopedics, ophthalmology, otolaryngology, gynecology, urology, and pediatric surgery.

In the otorhinolaryngology area, dehydrated solvent–dried fascia (Tutoplast) is used in surgical interventions such as frontobasal fracture, fascial paralysis, tympanoplasty, septal perforation repair, orbital floor restoration, and facial plastic surgery.