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学 位 論 文 要 旨
Dissertation Summary

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論　文　名:　　Finite Element Dynamics of Human Auditory System
(Dissertation Title)　　Comprising Middle Ear and Cochlea in Inner Ear

中耳と内耳内の蝸牛とで構成される人の聴覚システムの有限要素動力学

The human ear can be divided into three main parts, namely the external ear, the middle ear and the inner ear. The middle ear consists of an eardrum and three ossicles, namely three tiny bones (malleus, incus and stapes) which linked by each other, and connected with the eardrum and the inner ear. The problem in the ear that makes the human being unable to hear sounds in one or both ears is known as hearing loss. Hearing loss is one of the most severe problem in usual life activity of the human being. WHO reports that over 5% of the world’s population have hearing loss. Conductive hearing loss is the most common case due to problem in the middle ear or outer ear at times. In the middle ear, conductive hearing loss occurs due to chronic middle ear infection or glue ear where fluids fill up the middle ear so that the eardrum can not move. The otosclerosis in which the ossicles in middle ear become stiff or the dislocation of the three ossicles causes severe conductive hearing loss. The eardrum with a hole also can result in the conductive hearing loss. The eardrum with a hole accompanies liquid discharge from middle ear through the ear canal. Closing the hole in the eardrum can prevent water entering in a middle ear and an ear infection. Conductive hearing loss can often be treated with a surgery using artificial ossicles. The closure of the eardrum with hole by surgery is myringoplasty. If it is possible to perform the simulation of dynamic behavior of the human ear system before the surgery, it must be very helpful.

The purposes of this study are to develop a three-dimensional model of human ear system, to simulate the dynamic behavior of human ear system containing middle ear system, cochlea in inner ear, ligaments, tendon and tensor tympanic membrane and to examine the proper material properties and dimensions of sliced materials used in myringoplasty using finite element analysis (FEA).

The three-dimensional model of human ear system was developed using CAD software (Solidworks 2015) with the shapes and dimensions considering by the other researchers. Then, the three-dimensional model was exported to the finite element analysis

software (Hypermesh) to perform dynamic analyses namely eigen-value, frequency response and time history response analyses. Six-node triangular elements and ten-node tetrahedron element were used for the eardrums and the ossicles in finite element analysis, respectively. The material properties of human ear system were defined considering previous published by the other researchers. Three types of boundary conditions, namely clamped, torsional springs and new boundary modeled with finite elements were used on the boundary of the eardrums.

In the dynamic analysis, the eigen-value analyses of the human ear systems and the four types of eardrums, namely a normal eardrum, an eardrum with a hole, an eardrum repaired by the sliced cartilage and the sliced material except cartilage were carried out. Using the eigen-value analysis, it was examined that the proper thicknesses of sliced cartilage were 0.45 [mm] to 0.45 [mm] and sliced material having the same material properties as the human eardrum was 0.1 [mm] by comparing the vibration modes and natural frequencies of the four types of eardrums. Then, the frequency response and time history response analyses of the human ear system had been carried out. In the time history response analysis, Formant frequencies and human voices were used as the frequencies of the external forces and input sound pressures, respectively. It was confirmed that the calculation method in this study can perform dynamics analysis of human ear system containing middle ear, cochlea, ligaments, tendon and tensor tympanic membrane. Predictions from the model in this study may be useful to medical department in researching new surgical reconstruction and provide useful information for the design of prosthesis in the human ear system.