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Relaxation Effect in Implanted Human Middle Ear

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Abstract: As human beings, we have five basic senses: vision, hearing, balance, smell taste and touch. Hearing is one of the most important of them because it enables us to communicate with words and receive sound stimuli from the environment. For this reason it is one of the most difficult and complex systems in the human body to model as a mechanical system. Those models do not only help to recreate the phenomena that occur in the healthy ear, but also in ears with pathologies. By means of mathematical or numerical models, it is possible to study the damaged hearing organ and therefore to take action making it possible to repair or improve audibility. In human middle ear many tendons and ligaments are located this is the reason why relaxation effect is taken into consideration and it may improve model of human middle ear.

Keywords: middle ear, relaxation, ossicles vibrations

1. Introduction

The middle ear is one of the smallest biomechanical systems in the human body. Therefore a treatment of the ear is especially demanding task. An implantable middle ear hearing device (IMEHD) is one of the most promising technique, used in clinical practice, to improve the hearing process [1]. To investigate the IMEHD, a 5-degree of freedom (6dof) model of lumped masses is proposed that is also verified by a finite element model. Moreover, a relaxation effect of tendons and ligaments is taken into consideration in order to explain its role in sound transfer process. A problem of relaxation in the human middle ear is marginally treated in literature. Due to stress caused by acoustic waves the eardrum vibrates and the middle ear bones are set in motion. Each of these bones is connected with the temporal bone by ligaments and tendons. Motion mentioned above is causing stretching and compression in those tissues. Therefore it is necessary to study about the significance of the relaxation phenomenon in middle ear.

2. Results and Discussion

The model of intact human middle ear [Fig. 1a] was designed by 3D scanning of a human temporal bone. The eardrum, the malleus, the incus and the stapes was separated and then they have been scanned. The obtained parts was connected each other in CAD software. Moreover, the ligaments and tendons were created in CAD and connected to the bones. A part imitating cochlea and it’s oval window was created for connection of the stapedial annular ligament (SAL).

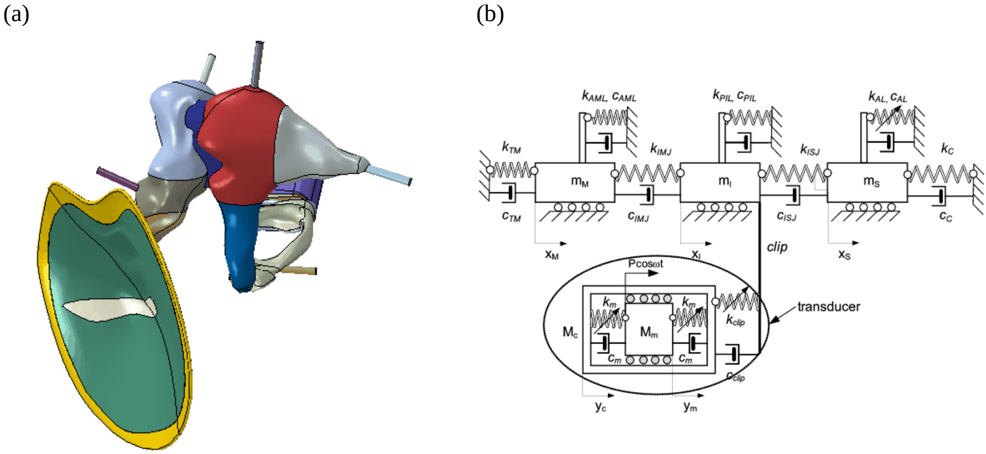

Fig. 1. 3D finite element model of intact human middle ear (a), lumped mass model of implanted middle ear.

The most demanding aspect of Finite Elements Method modelling of the middle ear is determining the boundary conditions of the tendons and ligaments. Appropriate boundary conditions of the system allow for proper reproduction of the occurring movements in the middle ear as a result of being forced by an acoustic wave onto the eardrum. The FEM model is required to get reference behaviour of the intact ossicular chain.

Simultaneously, the lumped mass model of implanted middle ear (5 degree of freedom), presented in Fig.1b was analysed to explore an influence of an middle ear implant and relaxation effect on sound transmission.

In result, the relaxation effect can shift resonance of the middle ear. Considering a simplified three-mass system of intact middle ear which every mass corresponds to one ossicle (malleus, incus and stapes respectively), a shift of the second resonance can be observed as a consequence of relaxation. By increasing the adopted relaxation time, the shift enlarges and the amplitude decreases. Exceeding the specified value of the relaxation time, we do not get any further changes, however, when the relaxation time is short this effect is not negligible and brings significant changes.

3. Concluding Remarks (10 point, bold)

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