Myringosclerosis and Otosclerosis – Their Effects in the Stapes Footplate

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ABSTRACT

The ear connects people to the outside world and contributes to sense of balance. However, a number of disorders can interrupt this perfect state, resulting in hearing impairment. Middle ear pathology, like myringosclerosis or otosclerosis is frequently seen and its early treatment is crucial to prevent others worst situations. The myringosclerosis is a formation of dense connective tissue in the eardrum, not usually associated with hearing loss. Otosclerosis is an abnormal growth of bone near the stapes and can result in conductive and/or sensorineural hearing loss [4].

In this work, a 3D solid model of tympano ossicular chain was built [2] with the integration of an improved membrane model [1], based on the finite element method, using the ABAQUS software. The ossicles (malleus, incus and stapes) were considered isotropic and the eardrum orthotropic. The material properties were obtained by literature [5]. The ligaments that connect the ossicles to the cavity tympanic walls have a hyperelastic behavior being a Yeoh model applied. The strain-energy function Ψ, for the Yeoh model can be written as [3]:

$$\psi = c_1(I_1 - 3) + c_2(I_1 - 3)^2 + c_3(I_1 - 3)^3 \qquad (1)$$

where I_1 is the first right Cauchy-Green strain tensor invariant, being c_1, c_2 and c_3 constants. To simulate the muscle activation of two muscles (tensor timpani and stapedius) the model of Hill was used. The load applied in the eardrum for simulation of the vibro-acoustic behavior of the middle ear was equal to 120 dB SPL (20 Pa).

Myringosclerosis simulation was done by assigning to the eardrum double rigidity when compared with the normal eardrum, given the absence of properties in the literature. From Fig.1, one can compare the displacements obtained at the stapes footplate on the normal model and considering the eardrum completely struck by myringosclerosis. Only a slight difference is observed for low frequencies, which is according to the clinical data that do not associates the myringosclerosis with large hearing loss. The second simulation concerning otosclerosis consists in the increase of the stiffness of annular ligament, two, five and ten fold, when compared with the model representative of the normal ear.
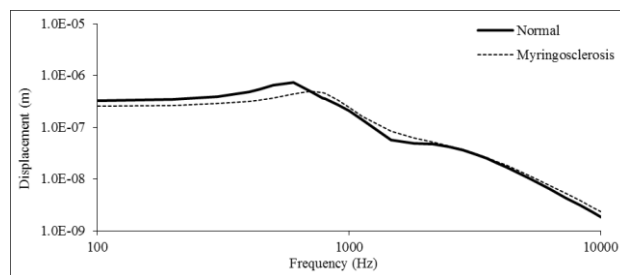
Figure 1: Staples footplate displacement, comparing normal model with myringosclerotic eardrum.

There was found a decrease of the displacements for all frequencies, with the increase of stiffness of annular ligament. This can indicate that if the otosclerosis is more intense, it leads to a greater hearing loss.
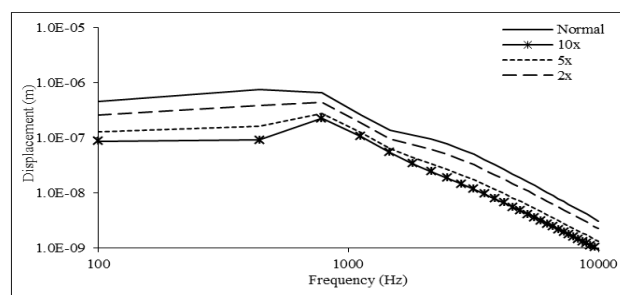

Figure 2: Staples footplate displacement, comparing normal model with different simulations of otosclerosis.

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