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Evaluation of laser vibrometry as diagnostic utility by means of a simulation model of the middle ear

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Laser Doppler Vibrometry has already been used in clinical studies to investigate its potential as a diagnostic utility. It is aimed to distinguish the different pathologies of conductive hearing loss and to evaluate the quality of reconstructive middle ear surgery. The purpose of this work is to simulate the different pathologies and their influence on the transfer function in order to show what is possible to distinguish in clinical measurements. We used a Finite Element Model of the middle ear for the investigations. Calculations were performed accordingly to the clinical measurements to get comparable results. The displacement of the umbo was calculated with applied sound pressure at the tympanic membrane. Harmonic analysis in the frequency range from 200 to 5000 Hz was used to calculate the transfer function. Calculations were done for intact middle ears with different sets of parameters to account for the individual variations and for the following pathologies: malleus and incus fixation, chain interruption, stiffening of annular ligament (otosclerosis), imperfect prosthesis reconstruction. The magnitude of the transfer functions varies by about 10dB due to the individual variations. Stiffening of the annular ligament leads to a reduced magnitude in the low frequency range and a change of the overall slope of the transfer function. Ossicular chain interruption gives a clear resonance peak below 1000 Hz. Imperfect prosthesis coupling produced only minor changes in the transfer function as long as the prosthesis is not completely dislocated. Malleus and incus fixation reduces the magnitude of the transfer function in the whole frequency range if bone like fixation is assumed. Results of the simulations are in good agreement with some clinical studies using the laser vibrometry. Stiffening of the annular ligament lead to the same characteristics in the transfer function as measurements on otosclerotic ears. The same holds for ossicular chain interruption. Both pathologies can be clearly distinguished from normal ears by means of the calculated transfer functions. Malleus and incus fixation can only be surely detected if the fixation is nearly rigid.