Design and Modeling of Human Middle Ear for Harmonic Response Analysis

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Abstract : The human middle ear (ME) is a delicate and vital organ. It has a complex structure that performs various functions such as receiving sound pressure and producing vibrations of eardrum and propagating it to inner ear. It consists of Tympanic Membrane (TM), three auditory ossicles, various ligament structures and muscles. Incidents such as traumata, infections, ossification of ossicular structures and other pathologies may damage the ME organs. The conditions can be surgically treated by employing prosthesis. However, the suitability of the prosthesis needs to be examined in advance prior to the surgery. Few decades ago, this issue was addressed and analyzed by developing an equivalent representation either in the form of spring mass system, electrical system using R-L-C circuit or developing an approximated CAD model. But, nowadays a three-dimensional ME model can be constructed using micro X-Ray Computed Tomography (μCT) scan data. Moreover, the concern about patient specific integrity pertaining to the disease can be examined well in advance. The current research work emphasizes to develop the ME model from the stacks of μCT images which are used as input file to MIMICS Research 19.0 (Materialise Interactive Medical Image Control System) software. A stack of CT images is converted into geometrical surface model to build accurate morphology of ME. The work is further extended to understand the dynamic behaviour of Harmonic response of the stapes footplate and umbo for different sound pressure levels applied at lateral side of eardrum using finite element approach. The pathological condition Cholesteatoma of ME is investigated to obtain peak to peak displacement of stapes footplate and umbo. Apart from this condition, other pathologies, mainly, changes in the stiffness of stapedial ligament, TM thickness and ossicular chain separation and fixation are also explored. The developed model of ME for pathologies is validated by comparing the results available in the literatures and also with the results of a normal ME to calculate the percentage loss in hearing capability.
Keywords : computed tomography (μCT), human middle ear (ME), harmonic response, pathologies, tympanic membrane (TM)

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