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Conceptual design of the human middle ear

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If the functionality of the middle is considered mostly the ability of effectively transmitting sound energy from the air in the ear canal to the fluids in the inner ear is examined. However, to assess the ""quality"" of the middle ear it is necessary to consider also other aspects than the transmission of sound. The human middle ear turns out to provide a larger auditory frequency range, lower general parameter sensitivity and better protection of the inner ear than a columella ear. The favourable properties are best understood by regarding the vibrations of the ossicular chain under different conditions and for different kinds of excitation. The vibrations are provided as animations computed by means of a generalised circuit model. Simulations have an invaluable advantage compared with experiments: conditions can be altered very easily and exactly. Changing conditions can give much deeper insight than merely investigating the normal behaviour. To discover the particular features, animations of middle ear vibrations have been calculated for the normal chain and for impairments introduced by altered positions and by stiffening compliant elements such as joints and ligaments. Using the generalised circuit model translational and rotational components of the elastic elements can be varied independently of each other. The different conditions are examined for acoustic stimulation by an eardrum pressure and for mechanic excitation by shaking the complete tympanic cavity in three orthogonal directions. All the visualisations taken together reveal a remarkable conceptual design of the human middle ear: It is known since long that the incudomalleal joint acts as an element protecting the inner ear against external forces. But a robust overload protector requires fairly strong bony material. Therefore the incudomalleal joint is necessarily encased by heavy masses which tend to worsen the sound transmission. In the talk it will be shown that the design of the human middle ear does not only circumvent a decrease in transmission at too low frequencies, but even takes advantage from the mass centre formed by the malleus head and incus body. The surprising features are achieved by the particular shape of the ossicular chain in combination with a favourable design of the elastic elements involved.