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Computer modelling of static pressure changes in the middle ear

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The human ear is designed to respond to static or quasi-static pressure changes, which can result in displacements exceeding 0.5 mm, many thousands of times greater than the vibrational displacements at audiofrequencies. It has been suggested previously that the ossicular chain effectively 'decouples' at the incudostapedial joint under static pressure loading, in order to excessive prevent transmission to the inner ear. Previous work conducted in our group on fresh human temporal bones demonstrated that there is a gliding motion at the incudomalleolar joint.

The aim of this study was to investigate, using finite element modelling, the motion of the normal ossicular chain under static and quasi-static pressures, particularly to obtain a better understanding of how motion is affected by the stiffnesses of the incudomalleal and incudostapedial joints. As a starting point the incudomalleolar joint was assumed to be relatively stiff, in accordance with observations by Vlaming in 1987. The joint was modelled as a homogeneous and isotropic hard tissue with a Young's modulus identical to the ossicles (12,000MPa). The less rigid incudostapedial joint was modelled as homogeneous and isotropic ligamentous tissue with Young's modulus of 0.6 MPa. These stiffness values have been used by our group and by others in previous finite element models.

Deformation of the umbo under static pressure was found to be similar to our previous experimental findings. The variation of joint stiffnesses had very little effect on umbo deformation, but was found to have an important influence on the deformation of the stapes centre footplate. The effect of incudostapedial joint stiffness was greater than that of the incudomalleal joint. While the stiffer joints aided sound transmission, the high modulus of the incudomalleal joint used in finite element models precludes movements of more than a few tens of micrometres under static pressure, suggesting that a lower modulus would be more realistic. Decreasing the joint stiffness does, however, impact adversely upon sound transmission efficiency.