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Basilar membrane displacement with opened and occluded oval window and bone conduction

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Material: During stapedectomy the stapes footplate is removed completely. With the opened oval window the hearing thresholds with bone conducted stimulation show a constant increase in all patients. This clinical finding is caused by the changes of the hydromechanical sytem, which is sealed at the oval window in the physiological and otosclerotic case.

Methods: To further study this effect we used a three dimensional Finite Element (FE) Model to evaluate the different case numerically. The lymph is idealized by a nearly incompressible and inviscid fluid with the mechanical parameters of water. The ambient bone is represented by fixed and immovable nodes as the normal boundary condition, but these may be loaded to implement the external pressure acting during bone conduction. There are four interfaces between movable elastic structures. These are at the inner areas of the stapes footplate and the round window and the upper and lower areas of the basilar membrane (BM). Further foramina like an open aqueductus cochlearis or the saccus endolymphaticus are not considered for the present. With these assumptions we are able to verify experimental findings and furthermore simulate states, which are difficult to make up.

Results: In all cases the level of stimulation was 70 dB(SPL) equivalent to 63.2 mPa. With a normal elastic round window and a fixed footplate the maximum BM displacement is about 0.014 nm, which will be the reference for the results with bone conduction because it is almost independent from the frequency of stimulation. In case of a completely removed footplate the maximum BM displacement increases between 750 Hz and 4 kHz and is maximal for 1500 Hz (0.04 nm or 9 dB). The reduction of the foramen size, which might represent the piston hole during stapedotomy causes a decrease of the maximum BM displacement by 2 dB. In conclusion the results confirm actual clinical findings during stapes surgery. Because of the flexibility of the FE Model further settings which are difficult to realize in experiments can be studied in the future.