Contribution ID: **13** Type: **not specified**

The human middle ear in motion: visualization and movement quantification using dynamic synchrotron-based X-ray microtomography

Characterizing the movement of the middle ear ossicles during sound transmission is of prime interest in clinical research. However, the small size, the location within the temporal bone, and the tiny movements of the three ossicles of the human middle ear make this type of measurements extremely challenging.
In this work, we use dynamic synchrotron-based X-ray phase-contrast micro-tomography to visualize the 3D motions of the intact human tympanic membrane and ossicular chain under acoustic stimulation. An in-house built fast read-out system coupled with a specific post-gating algorithm provided the temporal capability to resolve periodic micromotions up to 750 Hz.
A high-throughput pipeline optimized for the large tomographic datasets enabled to quantitatively describe the rigid-body motion of the ossicles from seven fresh-frozen healthy human ears stimulated at various acoustic frequencies and intensities. The displacement of several points of interest within the ossicular chain were analyzed and compared to the motions currently found in literature.

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