3D RECONSTRUCTION OF THE OSSEOUS INNER EAR STRUCTURES BASED ON MICRO-CT SCANS

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INTRODUCTION

Geometrical features of the osseous labyrinth force the application of sophisticated techniques to visualize its anatomy and topography. For a long time spiral computed tomography has been used to assess the inner morphology of the temporal bone. In recent years three-dimensional volume-rendered images obtained from microtomography opened new cognitive horizons in examining tiny biological objects. This modality allows for creation of cross-sections of a 3D-object with high resolution that may extend into the range of light microscopy.

MATERIAL AND METHODS

Macerated human temporal bones were investigated using micro-CT scanner (Skyscan 1172, N.V., Aartselaar, Belgium). Projections were captured along the long axis of the petrous bone and reconstructed using a software NRECON based on the Feldkamp algorithm. From the series of micro-CT scans volumetric models of the petrous bone were generated and virtually sectioned. For this purpose we used CTVox , CTAn, CTVol, and MeshLab softwares. Reconstructions of the osseous structures were based on a large number of micro-CT scans which varied from 1600 to 2000 per one petrous bone. An average dimension of each scan was 1200×1200 pixels, and the pixel size was equal 27.0 µm. This provided high accuracy in modeling and enabled approaching to virtual appearance of the osseous components of the inner ear.

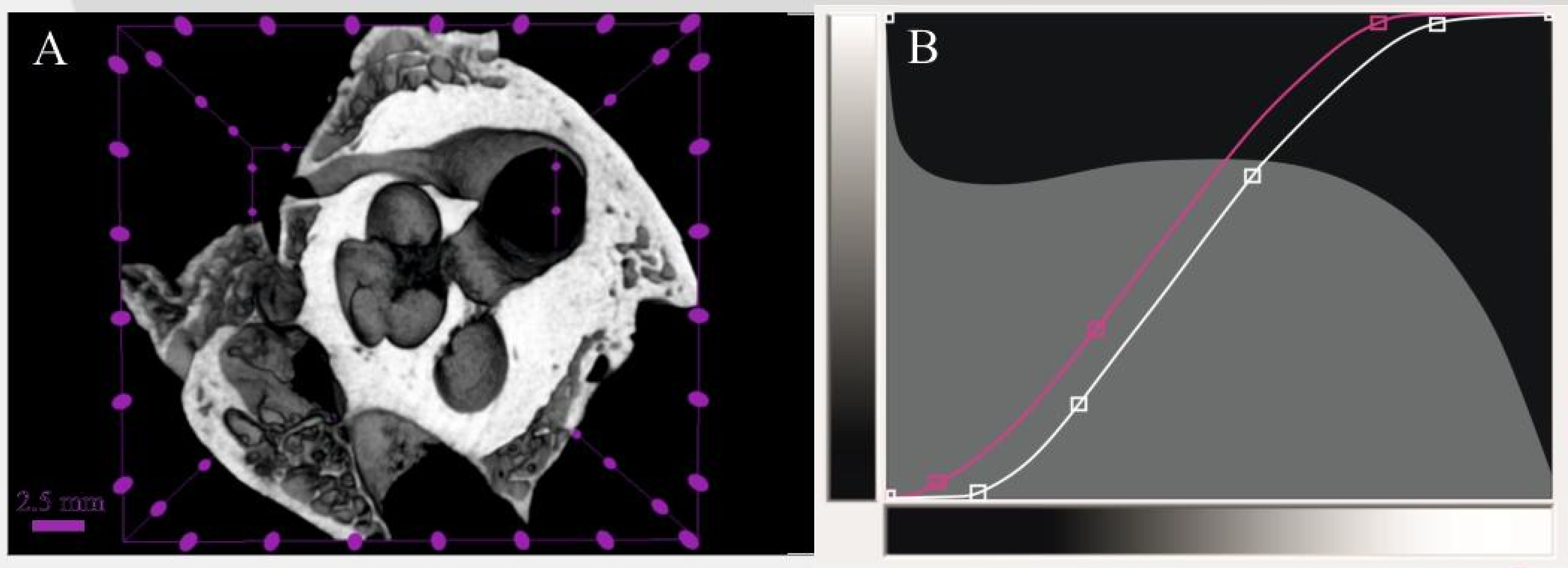


Fig.1. Volume rendering of the cochlea (A) and a graph of the transfer functions for luminance (white) and opacity (magenta) channel (B). This way of imaging in the cross section reveals inner components of the cochlea e.g. the modiolus.

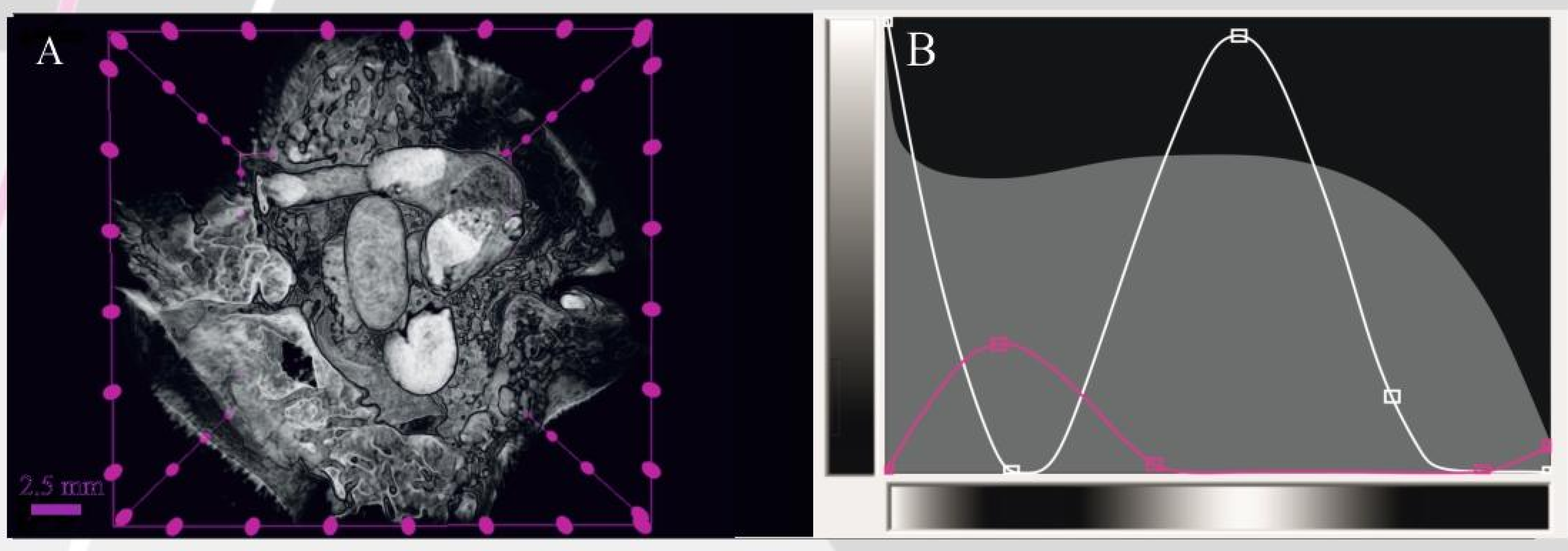


Fig. 2. Volume rendering of the cochlea according to polynomial transformation of the luminance and opacity channel. Tubular structures look like a endocast (A). Transfer functions designed to visualize air filling the bone cavities or canals, instead of bone (B).

RESULTS

Performed 3D reconstructions allowed to visualize the osseous structures of the inner ear including cochlea, the semicircular canals and adjacent structures embedded in the petrous bone. We found out that combination of the polynomial and logistic functions were optimal for controlling luminace and opacity channels. As the final product of this study we obtained digital models of the osseous components of the inner ear which can be viewed at different angles on the computer screen.

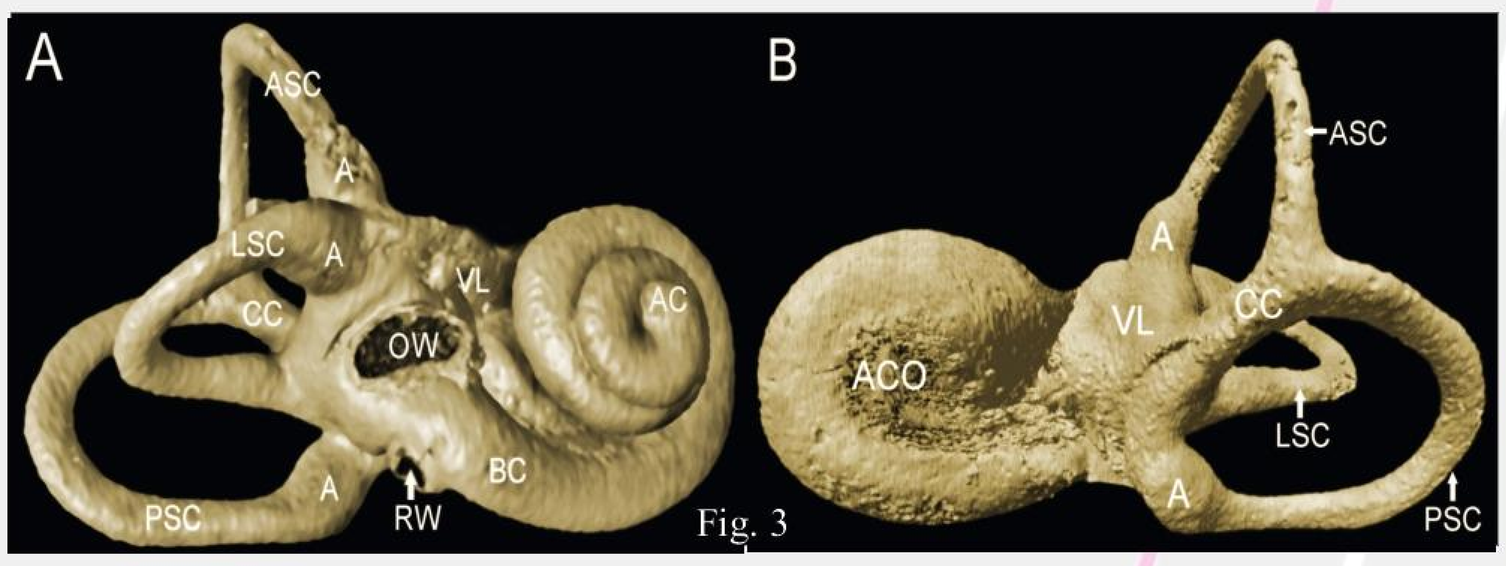
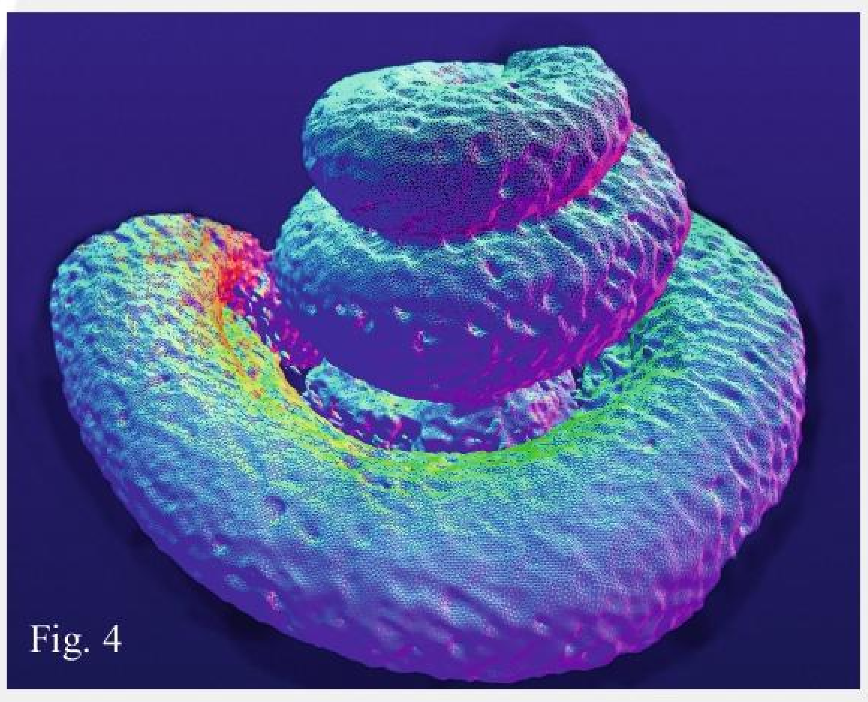


Fig. 3. Digital model of the osseous labyrinth. ACS - anterior semicircular canal, LSC - lateral semicircular canal , PSC - posterior semicircular canal, CC - common crus, A - ampulla, VL - vestibule, OW - oval window, RW - round window, BC - basal turn of the cochlea, AC - apex of cochlea, ACO - cochlear area. A - anterolateral view, B - posterosuperior view.



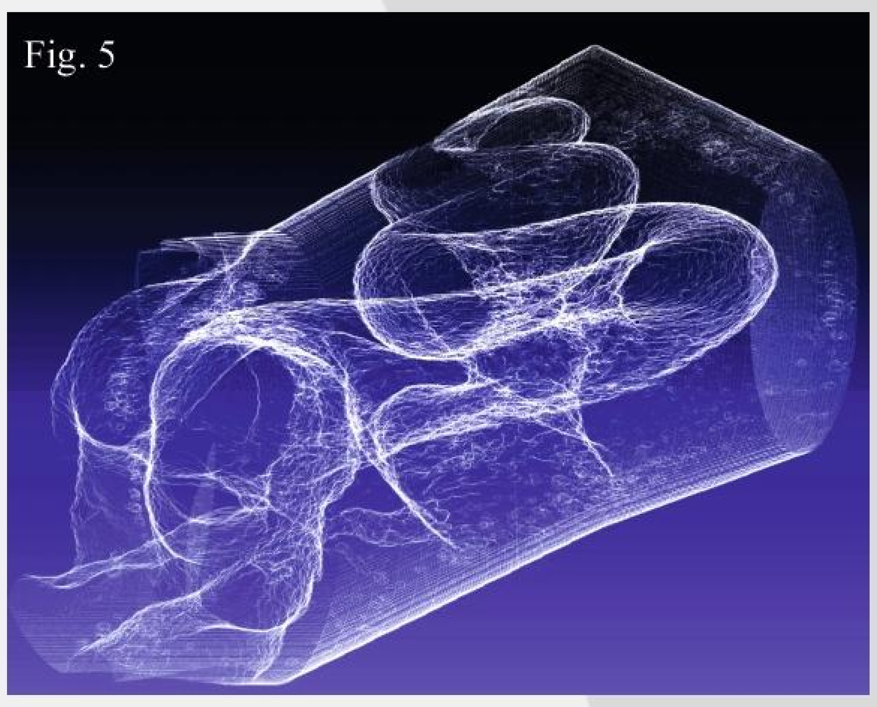


Fig. 4. A computer model of the cochlea created by image-based meshing process.
Fig. 5. Rendering with the aid of X-ray shading algorithm. The helicoid presents a warped geometric surface of the cochlea.

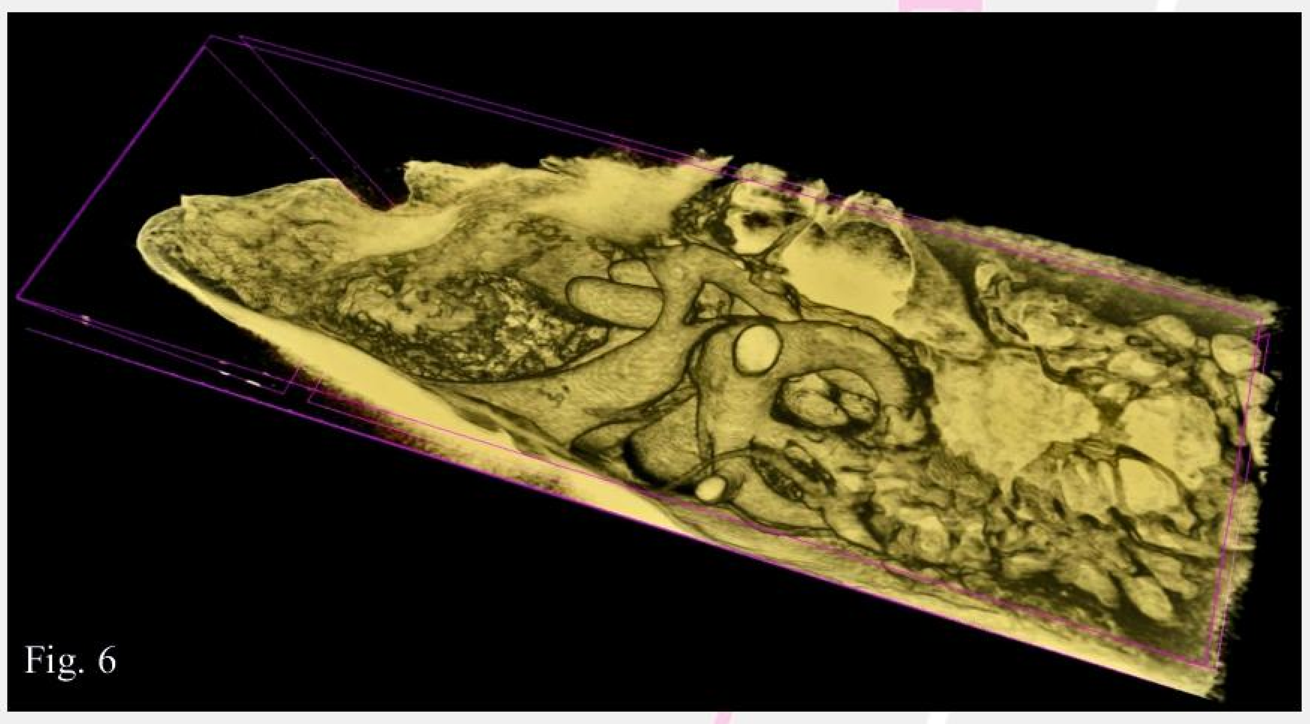
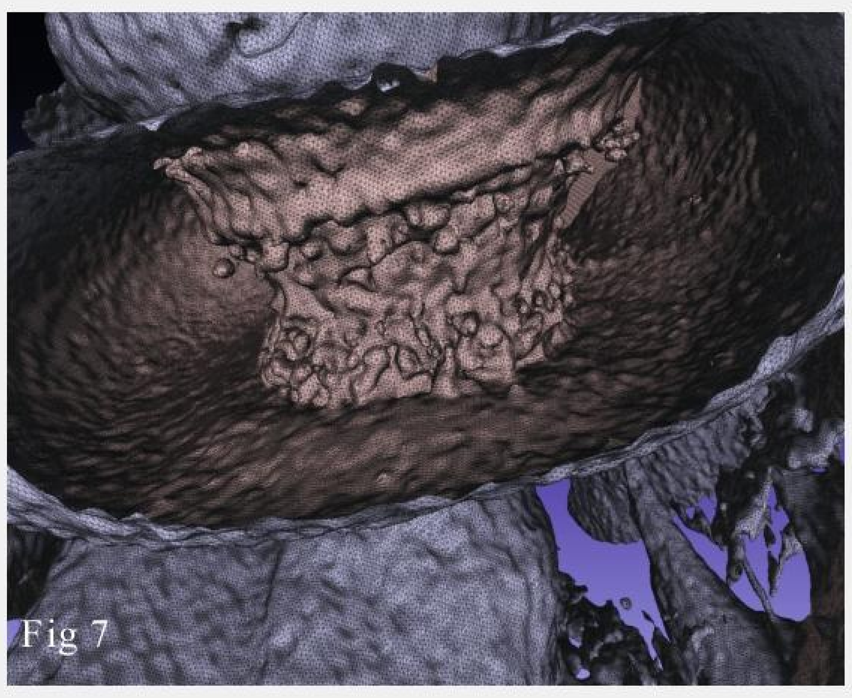


Fig. 6. 3D view of the osseous labyrinth after adding lighting effect and polynomial modification of the transfer function. Bony components are transparent, contrary to the lumen of the canals which are opaque objects.



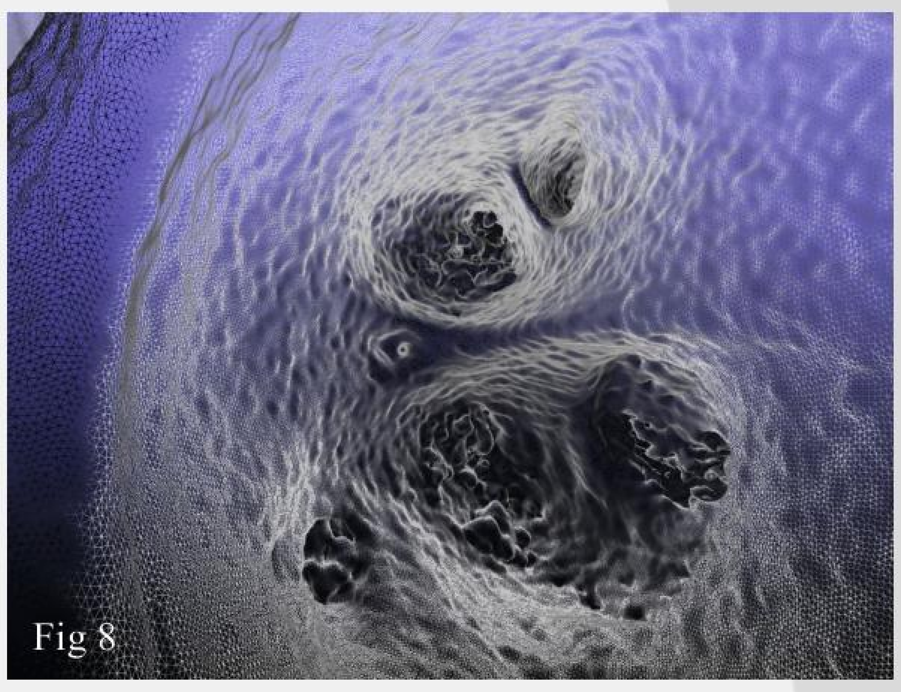


Fig. 7. Surface model of the modiolus represented by rendered polygonal mesh.
Fig. 8. Inner surface of the internal acoustic meatus in the perpendicular projection.

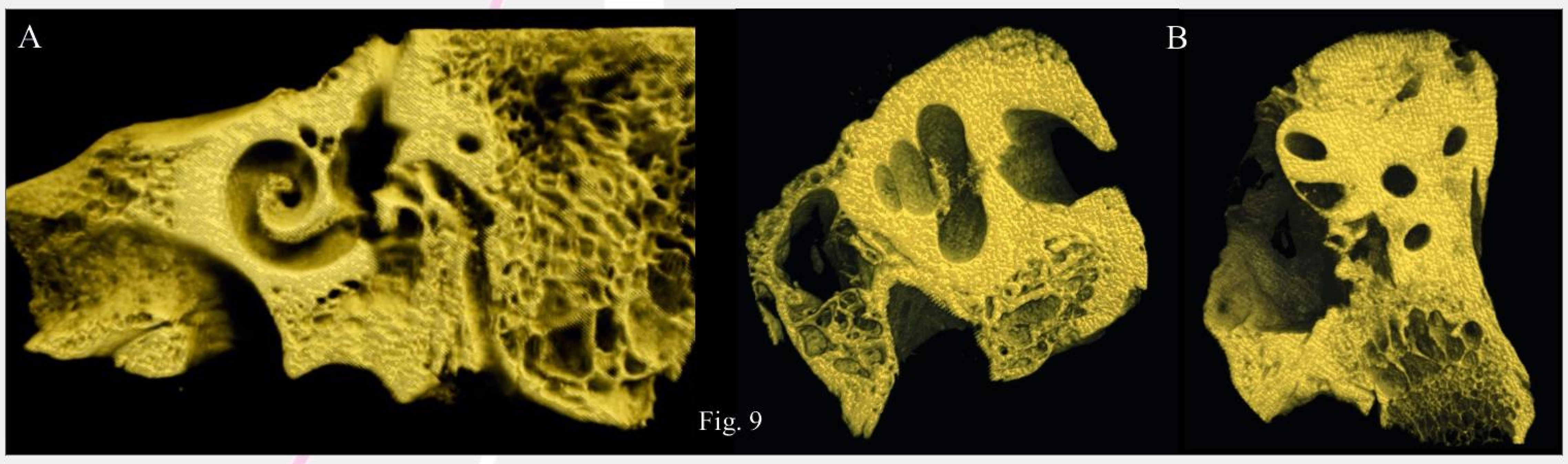


Fig. 9. Volume rendering image illustrating interior of the petrous bone in the region of the inner ear in the sagittal section (A) and transverse sections (B). The lighting effect models the reflection of light and shadows which provide additional depth cues and strongly enhance the perception of surface relief and other small-scale structures.

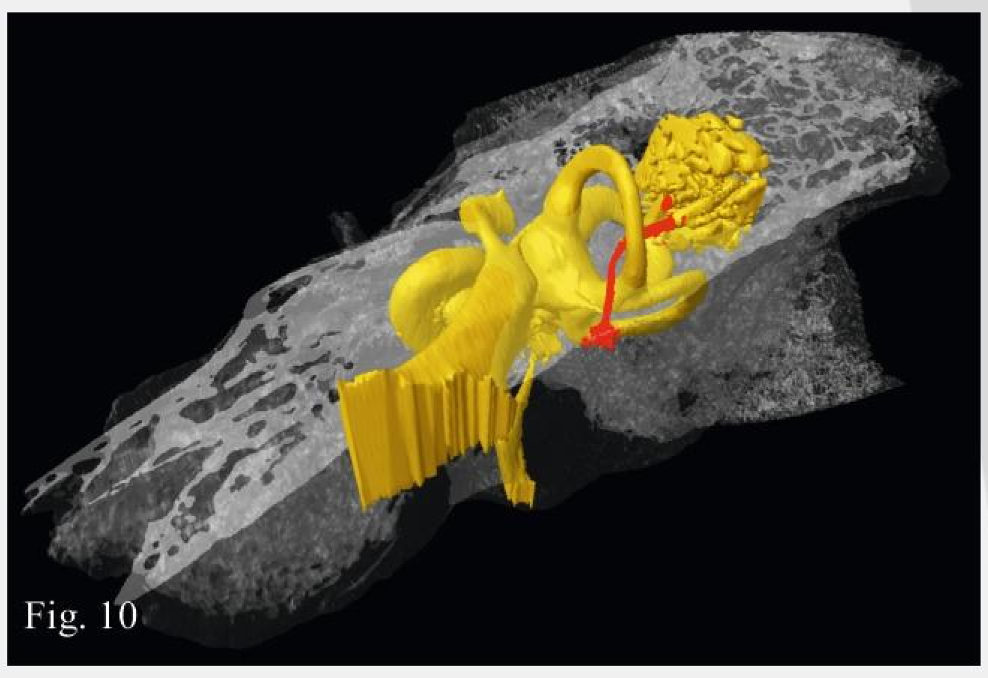


Fig. 10. A model of the petrous bone in the horizontal section showing the labyrinth (yellow) and the subarcuate canal (red). Visible connection between the subarcuate canal and the mastoid cells.

CONCLUSIONS

Microcomputed tomography delivers comprehensive images which simplify understanding of complexity of the petrous bone. Three-dimensional models of the osseous inner ear structures may be used in comparative morphological studies and become helpful for learning and teaching anatomy. Hence, they enable to calculate morphometric parameters in 3D space.