A Method for Building Individualized Two-Dimensional Artificial Cochlea Models

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Objective

Two-dimensional artificial cochlea models are frequently used in the development and characterization process of new electrode arrays for cochlear implant systems. Insertion force measurements are one of the main applications.

Artificial cochlea models (ACM) are often used in place of cadaveric temporal bones due to their easy availability, low cost and most importantly the reproducible conditions for repeated insertions

Typically, these ACMs are two-dimensional (2D) representations of an average human cochlea and may be milled out of a slippery material, like e.g. polytetrafluoroethylene (PTFE).

Some research questions require the use of individual instead of average geometries. For this purpose we established a method to build a geometrically more realistic replica of the individual cochlea specimen.

Software

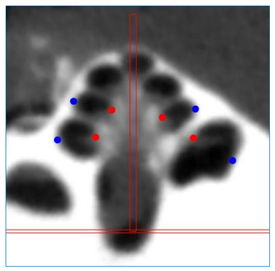
The COMET program (Cochlear Measurement Tool) is an in-house developed software (Lexow et al. 2016 Int J CARS 11:1855-1869) which enables length measurements of the spiral cochlea as well as segmentation of the cochlear geometry.

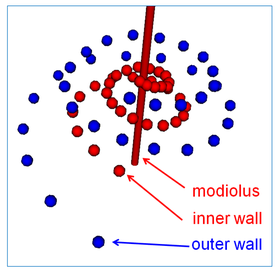
It is a custom-made DICOM viewer especially for the cochlea featuring a rotating mid-modiolar slice plane which simplifies the placement of points in the corresponding cross-sectional plane (e.g. along the lateral wall). The relative angle to rotate the slice plane can be adjusted to fit individual needs.

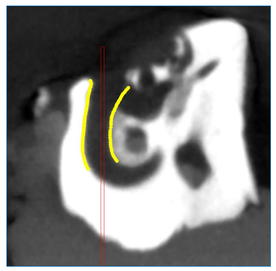
Methods

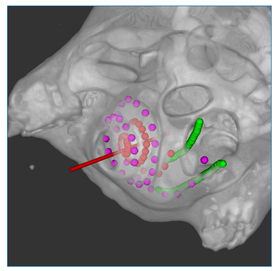
Segmentation

- Porcine cochlea specimens were used to establish the method
- Cut down to a small piece exclusively containing the cochlea, glued on a sample holder for controlled positioning
- Cone-beam computed tomography (CBCT, Accuitomo, Morita, voxel size 0.08 mm) imaging was performed
- The shape of the inner and outer wall of scala tympani (ST) were segmented in steps of 22.5° around the modiolus using the COMET software
- Segmentation on the basal part was done with a tighter step wide



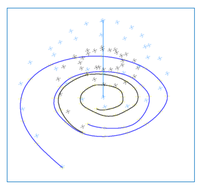


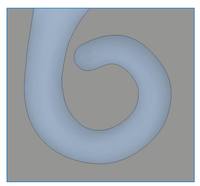


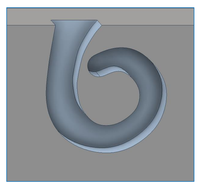


Develop the model

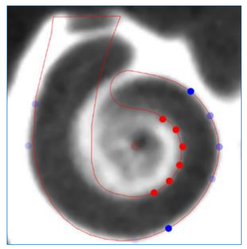
- Inner and outer walls projected onto a plane perpendicular to the modiolar axis
- 2D projected contours further processed using computer-aided design (CAD) software (Autodesk Inventor Professional 2015)
- The cochlea is modelled as a volume with 1.5 mm thickness
- This is modelled as a negative in a block of material

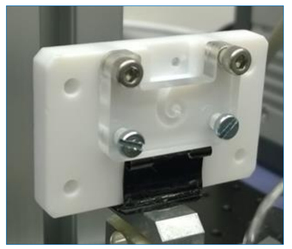






- Before milling the models a step for checking the accuracy was included:
- The produced STL models are loaded into the original DICOMs to check the position



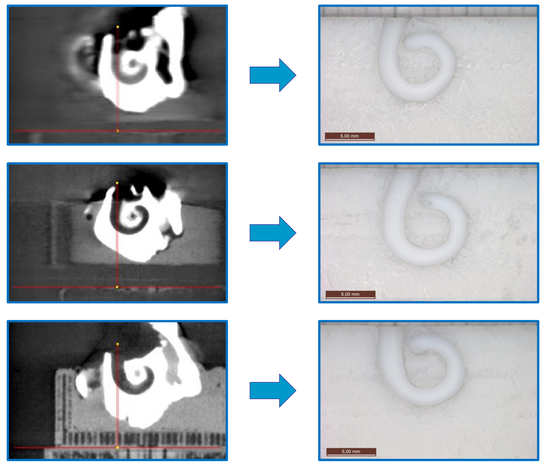


- This geometrical data can be exported and used in a computer numerically controlled (CNC) milling machine
- The models were milled out of a PTFE plate
- For use in the insertion force experiments the models are covered by a PTFE sheet and an acrylic glass disk

Results

With this method it is possible to build individualized two-dimensional artificial cochlea models out of any material which can be milled with a CNC machine or by 3D printing. A set of DICOM data of the desired cochlea geometry is needed as for example from CBCT or µCT scans.

Here a few examples:



This enables us to do insertion force measurements in a set of different geometrical models, like for example in a study where the use of PTFE for ACMs was validated. For this study ACMs whose geometry matched those of fresh temporal bone cochleae were needed. (on poster PS 62)

Further applications of this method are to test the effect of geometrical parameters on the insertion force.

Acknowledgement

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