Statistical Shape Analysis of the Human Middle Ear

Marcus Neudert, Steffen Ossmann, Matthias Bornitz

Introduction

In new middle ear implants development simulation models are becoming more and more valuable for predicting sound transmission characteristics. Realistic geometric representation is crucial in finite element models. Even though the models become more advanced they are generally based on the geometry of a single sample. Various studies have shown that the morphology of the middle ear displays large variations. Unfortunately most studies only published specific length measurements, which do not cover the complete variation of shape. Statistical shape analysis - a commonly used approach in the field of anthropology – can be used to describe the natural anatomic variations in the middle ear.

Material & methods

We evaluated micro-CT data of extracted, dried ossicles (malleus, incus and stapes) and of complete, unstained middle ear preparations. The voxel size of the imaging data was in the range between 10 and 19 µm (depending on the sample size). The relevant structures were semi-automatically segmented and further smoothed. Through a registration step the orientation bias was removed and a dense correspondence was established between the structures. The statistical shape model was then built by principal component analysis. The results were analyzed and compared to anatomical data. The geometric data was input into a finite element model of the middle ear and the middle ear transfer function was calculated.

Results & Conclusions

We obtained a statistical shape model of the human middle ear by analysis of micro-CT data that can represent the mean shape and its shape variations. Furthermore, we derived length measurements and relative angles to compare our findings with published data. Finally, we present preliminary results of the influence of the geometry on the middle ear transfer function predicted by our simulation model.