ON THE COUPLING BETWEEN THE INCUS AND THE STAPES

W.R.J. FUNNELL, S.J. DANIEL, B. ALSABAH AND H. LIU

McGill University, 3775 rue University, Montréal, QC, H3A 2B4, Canada
E-mail: robert.funnell@mcgill.ca

There is a thin bony pedicle joining the lenticular plate to the rest of the long process of the incus. We have previously presented a brief review of its anatomy; new histological observations in cat; and a simplified finite-element model of the long process, pedicle, lenticular plate, incudostapedial joint and stapes head in the cat. Low-frequency simulations suggested that there may be more flexibility in the pedicle than in the incudostapedial joint itself. In this paper the modelling work is extended: a 3-D model for the cat is shown which has a more realistic geometry, and a model for the human is presented.

1 Introduction

The incudostapedial joint is a synovial joint between the lenticular plate of the incus and the head of the stapes. There is a thin bony pedicle joining the lenticular plate to the rest of the long process of the incus. The pedicle is extremely fine and it is easy to overlook or misinterpret. We have previously presented a brief review of its anatomy; new histological observations in cat; and a simple finite-element model of the long process, pedicle, lenticular plate, incudostapedial joint and stapes head in the cat. Low-frequency simulations suggested that there may be more flexibility in the pedicle than in the incudostapedial joint itself [1].

In this paper a histology-based 3-D reconstruction of the cat lenticular process is presented which has a more realistic geometry than the simplified finite-element model. The modelling work is then extended to the human ear. First, a new 3-D reconstruction for the human lenticular process and stapes head is presented, based on x-ray micro computed tomography (μCT). Second, a finite-element model with simplified geometry is presented, along with simulation results.

2 Methods

The 3-D reconstruction for the cat is based on serial sections from a plastic-embedded incus of an adult cat. The sections were cut at a thickness of 1 μm, and every section was stained with toluidene blue and mounted. These are the same sections on which the dimensions of our previous model [1] were based.

The 3-D reconstruction for the human is based on a μCT dataset obtained using a SkyScan 1072 scanner, with an isotropic voxel size of 4.2 μm [2].

The 3-D reconstructions for both cat and human were produced using *Fie* and *Tr3*, locally developed computer programmes for image segmentation and 3-D surface triangulation. The software is available for free downloading [3]. For the

histological images, slide-to-slide alignment was done manually. For both data sets, structures of interest were outlined either manually or semi-automatically.

The configuration and material properties for the new finite-element model are the same as those of our previous model for the cat [1]. The dimensions of the model were estimated from the new human 3-D reconstruction.

3 Models and Results

Figs. 1 and 2 show 3-D reconstructions of the cat and human lenticular processes, respectively. Fig. 3 shows a preliminary simulation result for the simplified model of the human lenticular process. More bending is apparent in the pedicle than in the joint, similar to our previous finding for the cat.

Fig. 1. Cat reconstruction

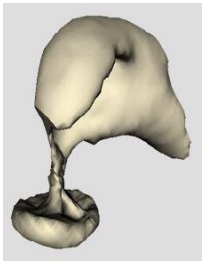

Fig. 2. Human reconstruction

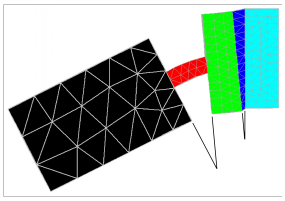

Fig. 3. Human simulation results

4 Discussion

Because the bony pedicle is very much thinner in one direction than in the other, it may provide hinge-like incudostapedial flexibility, thus controlling the degree of rocking of the stapes and affecting the nature of the input to the cochlea.

Acknowledgements

This work was supported by the Canadian Institutes of Health Research, the Natural Sciences and Engineering Research Council (Canada), and the Fonds de recherche en santé du Québec.

References

1. Funnell, W.R.J., Siah, T.H., McKee, M.D., Daniel, S.J., Decraemer, W.F., 2005. On the coupling between the incus and the stapes in the cat. *JARO* **6**, 9–18.
2. Alsabah, B., Liu, H., Funnell, W.R.J., Daniel, S.J., Zeitouni, A.J., Rappaport, J.M., 2005. Secrets of the lenticular process and incudostapedial joint. Ann. Mtg. Can. Soc. of Otolaryngol. Head & Neck Surgery, St. John's, Newfoundland.
3. Funnell, W.R.J., 2005: AudiLab software. http://audilab.bmed.mcgill.ca/~funnell/AudiLab/sw/