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Electrode insertion force measurements in porcine temporal bones

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Introduction

Measuring insertion forces in a cochlea bench model is a standard procedure for estimating trauma of cochlear implant electrode arrays. These measurements are done either in bench models made of various materials, for example PTFE, in combination with various lubricants, or in fresh frozen temporal bones. To answer the question how realistic these model materials are, we started an insertion force study with fresh never frozen temporal bones. Electrode insertion force measurement is not practical in living patients, access to human cadavers immediately post-mortem is difficult, and frozen/thawed temporal bones may have altered tissue properties. Therefore in this study fresh never frozen animal temporal bones have been used as a proxy to the living human cochlea.

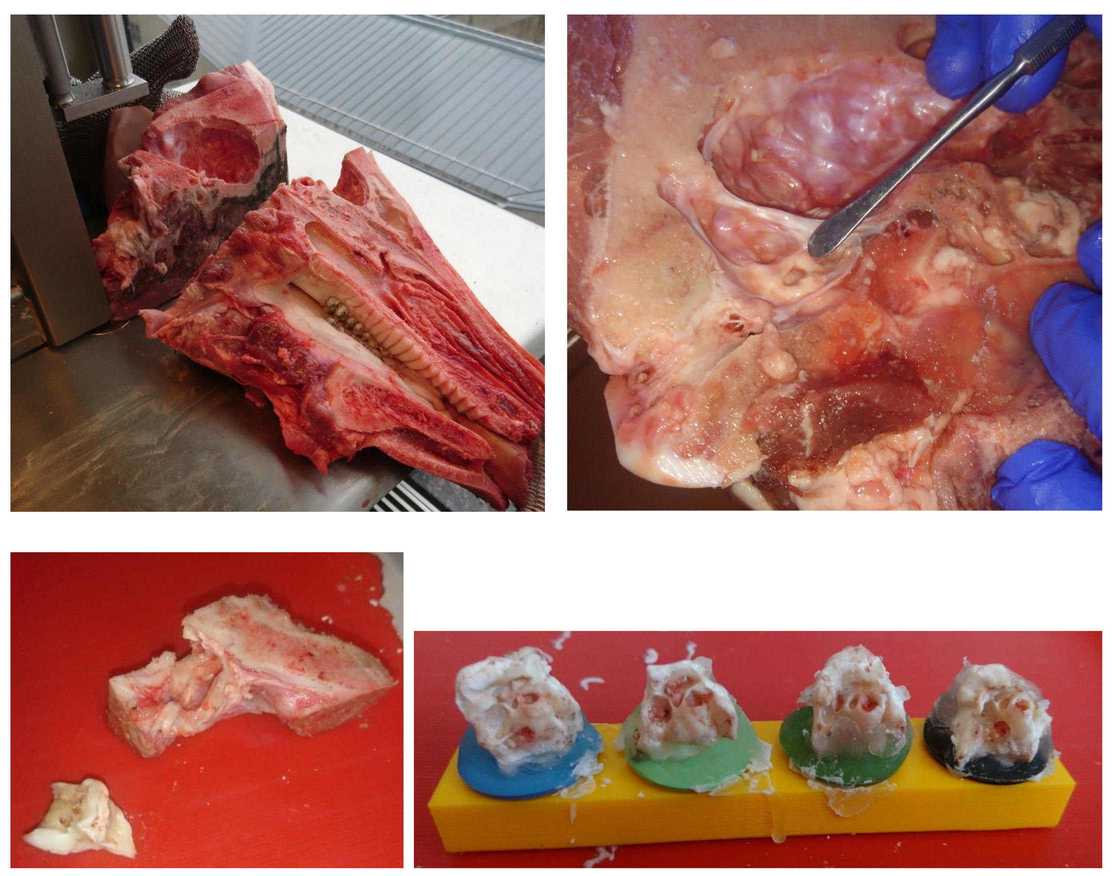

Fig. 1: Preparation of the porcine cochlea.

Animal selection

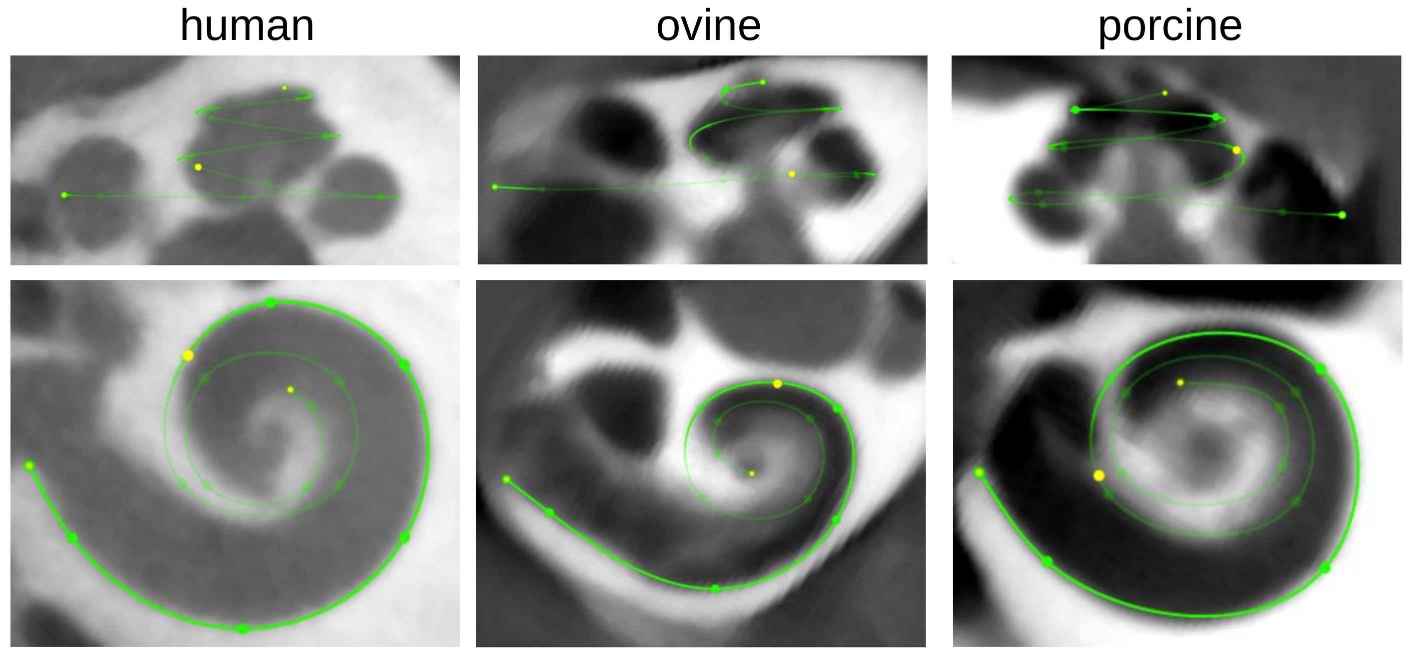

Fig. 2: Comparison of high resolution native cone beam CT.

Both sheep and pig heads were analyzed by CBCT and compared to human:

- The human cochlea has a length around 38 mm (1) in two and a half turns.
- The ovine cochlea in contrast is around 26 mm long with two turns. The most noticeable difference is a long basal part with a more narrow turn.
- The porcine cochlea is in the shape more similar to the human. It has a length around 35 to 36 mm with also two and a half up to three turns.

Fig. 3: Comparison of high resolution cone beam CT after electrode insertion (Cochlear Slim Straight).

The electrodes in both, ovine and porcine cochlea, are insertable up to 15 mm depth without buckling which corresponds to one turn. A deeper insertion might be possible in some temporal bones but this is not desired in this study. Based on the bigger anatomical similarities and the easier surgical access the pig was chosen to be used in the following insertion force studies.

Force measurement

- The cut down temporal bone specimens were glued to a holder which was mounted on a single axis load cell for the automated insertion force measurements.
- A dummy electrode based on the Cochlear Slim Straight electrode was inserted in the porcine cochlea to a depth of up to 15 mm.
- The measurements could be repeated in each bone up to four times. Sometimes the measurements could not be repeated more than two times, due to buckling of the electrode inside the cochlea.
- The temporal bone specimen were kept wet in between the processing steps and before the measurement.
- The insertion was done automated by a linear positioner with a speed of 0.5 mm/s.
- The measured insertion force curves are mean values from two to four curves in each temporal bone.

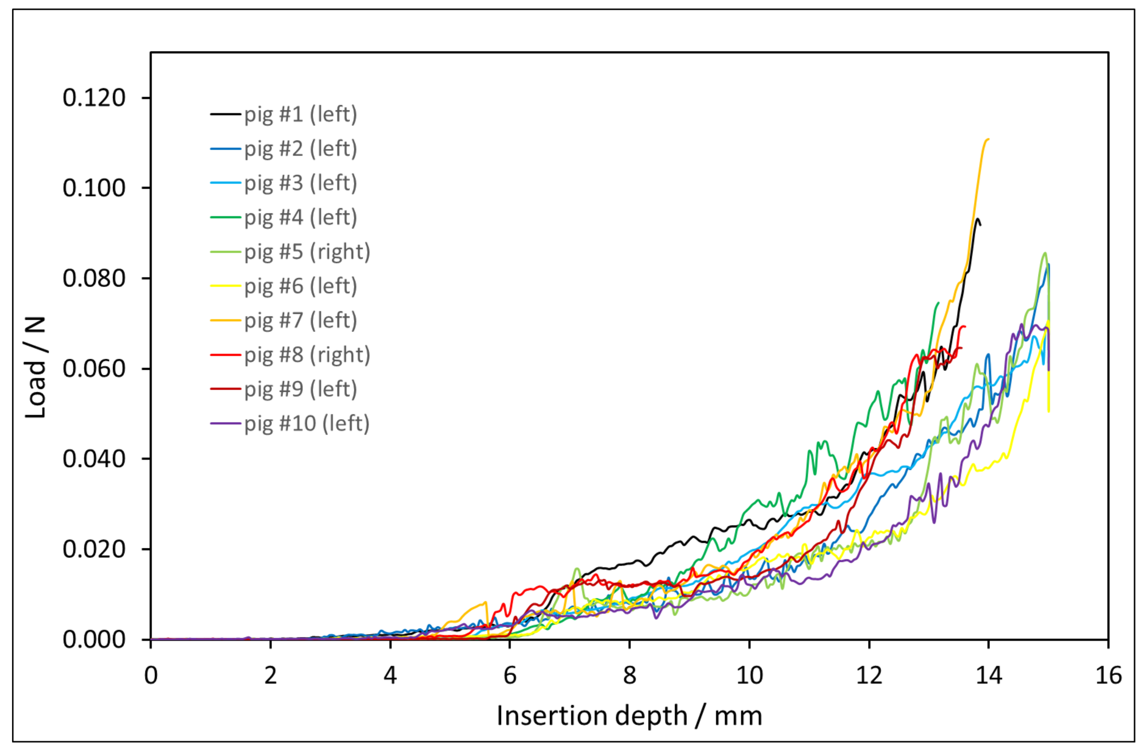

Fig.4: Insertion force curves in porcine cochlea.

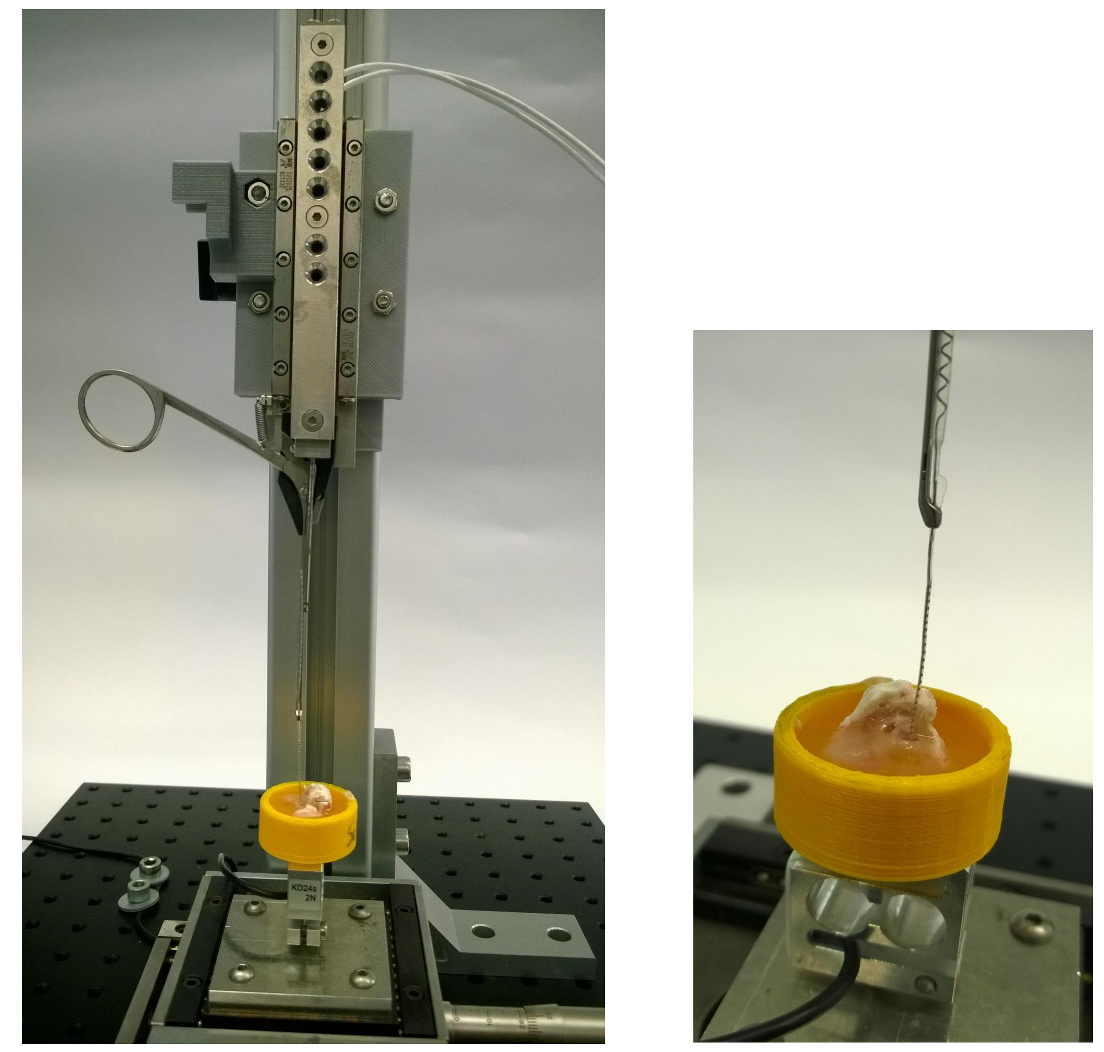

Fig.5: Setup for automated insertion force measurement with pig specimen and electrode dummy (enlargement).

Conclusion

We established the procedure to measure insertion forces in fresh porcine temporal bones. The insertion force curves have acceptable variances between the various temporal bones.
The next step is to produce bench models in a range of materials with cochlea spiral dimensions obtained from CBCT imaging matching those of the pig. Insertion forces will be compared, to identify the material whose friction characteristics best match the fresh pig cochlea, and, it is hoped, the living human cochlea.

References
(1) Würfel, W. et al.,2014, Hearing Res., 316, 65-72.

Acknowledgement
This study was financially supported by Cochlear Ltd. The authors thank Max Eike Timm for his support with analyzing the CBCT images and Silke Hügl for her support in building the automated insertion force measurement setup.

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