Appendix 1

Design of a 3D printed temporal bone model

The model is based on the computed tomography scans and micro-slicing images from an open-access file named 'Delta' from the OpenEar library of 3D models of the human temporal bone (27). These files contained automated segmentation (isolation) of individual structures such as the temporal bone, tympanic membrane, external auditory canal, internal carotid, tympanic and mastoid segments of the facial nerve in individual standard triangle (STL) files. Where structures were not identified on imaging or isolated by auto-segmentation, these structures were modelled with 3-Matic (Belgium), Meshmixer (California, USA) and Blender (Blender Foundation Amsterdam) to improve the anatomical accuracy for identification in dissection. This was conducted with collaboration between a biomedical design engineer, an Otolaryngology fellow and surgical trainee. This process was required for the following structures that were not already present in the Delta dataset: (I) the internal acoustic nerves (facial nerve, cochlear nerve, superior and inferior vestibular nerves) with a dural sheath, (II) the geniculate ganglion in continuity with the facial nerve, (III) first and second genu of the facial nerve in continuity and a facial nerve exiting the stylomastoid foramen, (IV) a prominent digastric ridge modelled into the mastoid bone, (V) a prominent stylomastoid process for readily available identification, (VI) incudo-malleolar joint (IMJ) and incudo-stapedial joint (ISJ) modelled as separate structures so as to be printed with a separate material from the bone to allow the ossicles to be mobile, (VII) the stapedial tendon and ossicular ligaments to allow suspension of the middle ear bones within its space, (VIII) a superior semicircular canal projected to the middle cranial fossa to resemble a prominent arcuate eminence, (IX) modelling of the otic capsule with perilymph and endolymphatic systems seen in *Figure 1*, (X) communication of the mastoid air cells with drainage hole to allow flushing of filler material from the scaffolding of the model, as seen in *Figure 2*, (XI) sinus dura mater.

After modelling, the individual parts were deemed to be accurate representations of all anatomic structures and the complete assembly of parts was imported to the printing software (GrabCAD Print). Pre-sets (such as 'Skull' and 'Ligament') were selected for each structure. Parts were 'prioritised' in cases where anatomic segments were overlapping on the software for printing in an order to ensure that the smaller and softer tissue structures were printed within the larger temporal bone. Soft smaller parts (for example the facial nerve) were prioritised over the larger harder parts (for example the bone) to ensure that these would be present and visible during dissection. The completed assembled model's overall size was increased by 10% to represent a realistic surgical size. This decision was decided after review by 3 senior OHNS surgeons advised that the model was printed smaller than real size which would also make its mounting on a holder and its dissection more difficult for junior OHNS surgeons.

The IMJ and ISJ were printed using bone material rather than soft ligament material to prevent damage and dislocation of the ossicles during the process of removal of filler material. This was identified as an issue during examination of the model's middle ear after mastoidectomy, which showed that the ossicles had been displaced by the cleaning process. The peri-lymphatic system was not aerated, or fluid filled but did have different materials to allow the dissector to identify a difference on entering the otic capsule under the microscope.

Testing of the infill or support materials for the mastoid bone and middle ear required several attempts to allow for void spaces within the model. PureGel and Gel support were used in sections of the mastoid air cell models and tested for efficacy in removing the filler material via drainage holes with the process of gentle water irrigation of air spaces, 2% sodium hydroxide, 1% sodium metasilicate solid bath for 12 to 18 hours, high pressure water irrigation and finally compressed air drying. This process was deemed to be the most suitable method of removal of filler material while preserving the ossicle integrity and mastoid spaces when the models were dissected and examined under the microscope by the junior OHNS and OHNS fellow.

References

27. Sieber D, Erfurt P, John S, et al. The OpenEar library of 3D models of the human temporal bone based on computed tomography and micro-slicing. Sci Data 2019;6:180297.

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