

Lend Me Your Ears: Comparing the Accuracy Of 3D Modeling vs. Microscopic Measurements of Ear Ossicles

Jennifer K. Wilburn and Katie A. Hemer

UCL Institute of Archaeology



SITE CONTEXT

Early medieval cemetery excavated beneath St Patrick's Chapel, Pembrokeshire, Wales

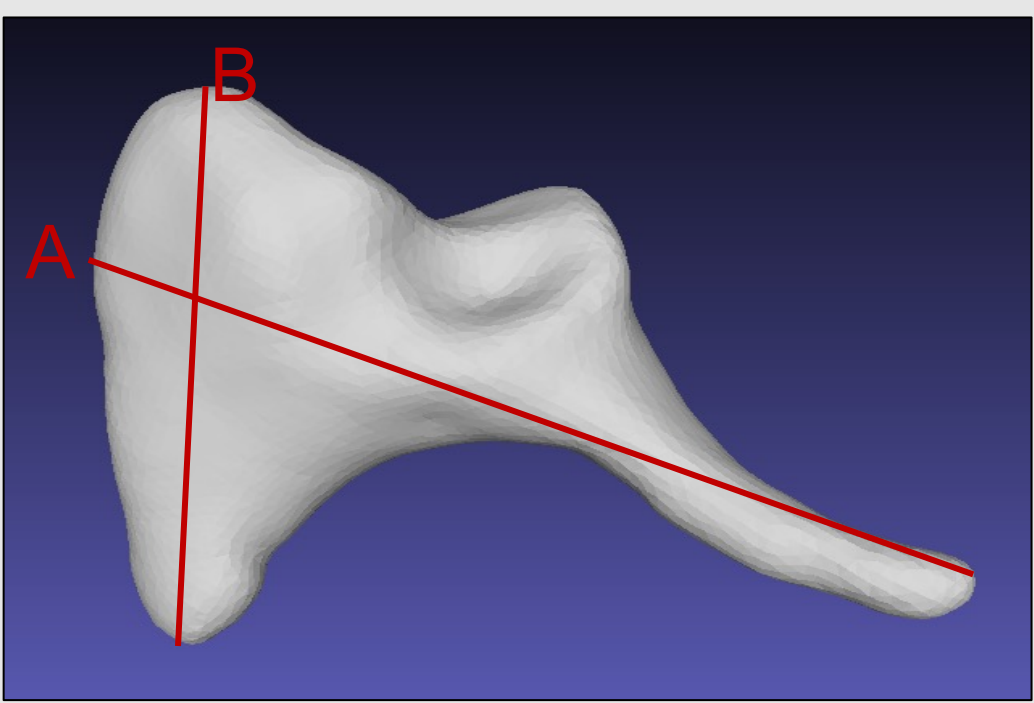
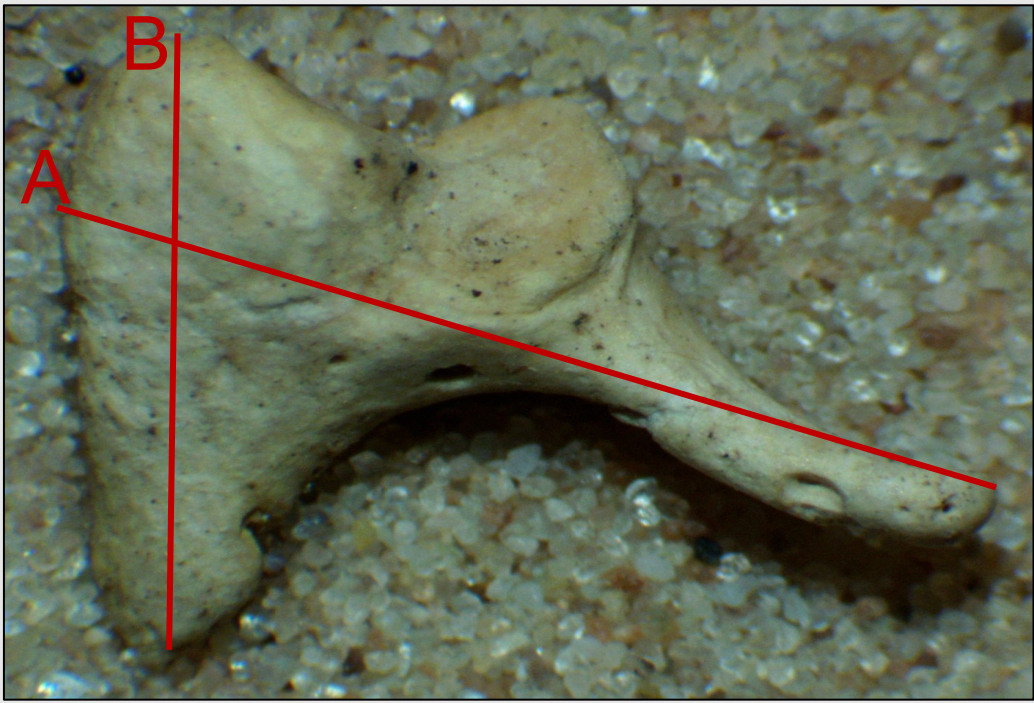
Radiocarbon dates: 8th – 12th century AD

Mixed cemetery population with ages ranging from perinates to mature adults

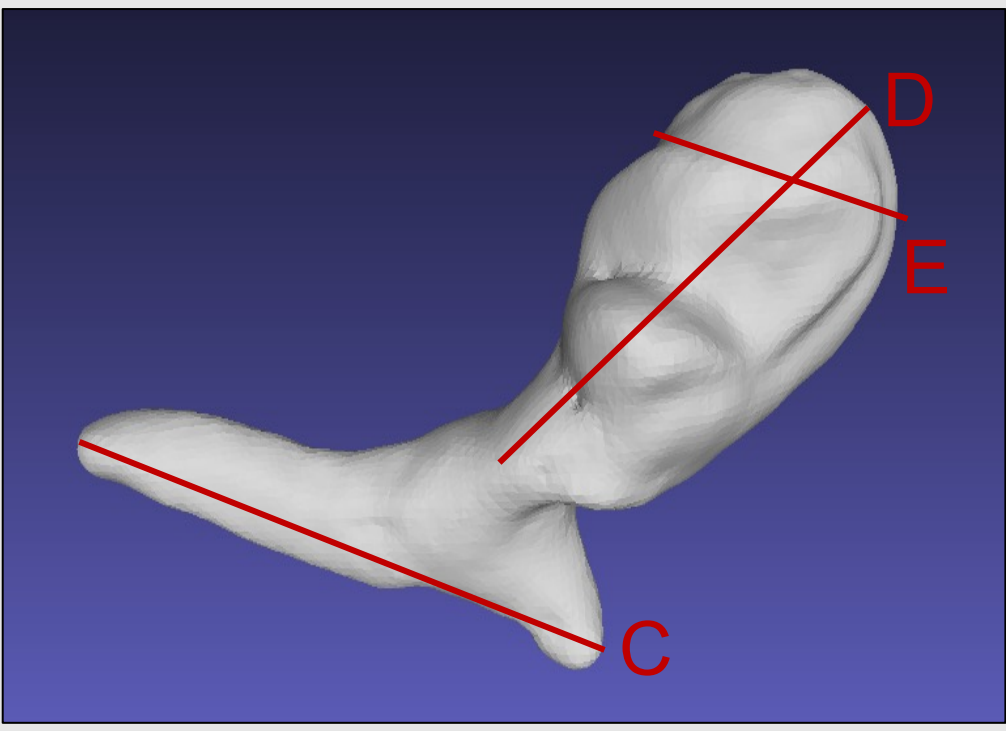
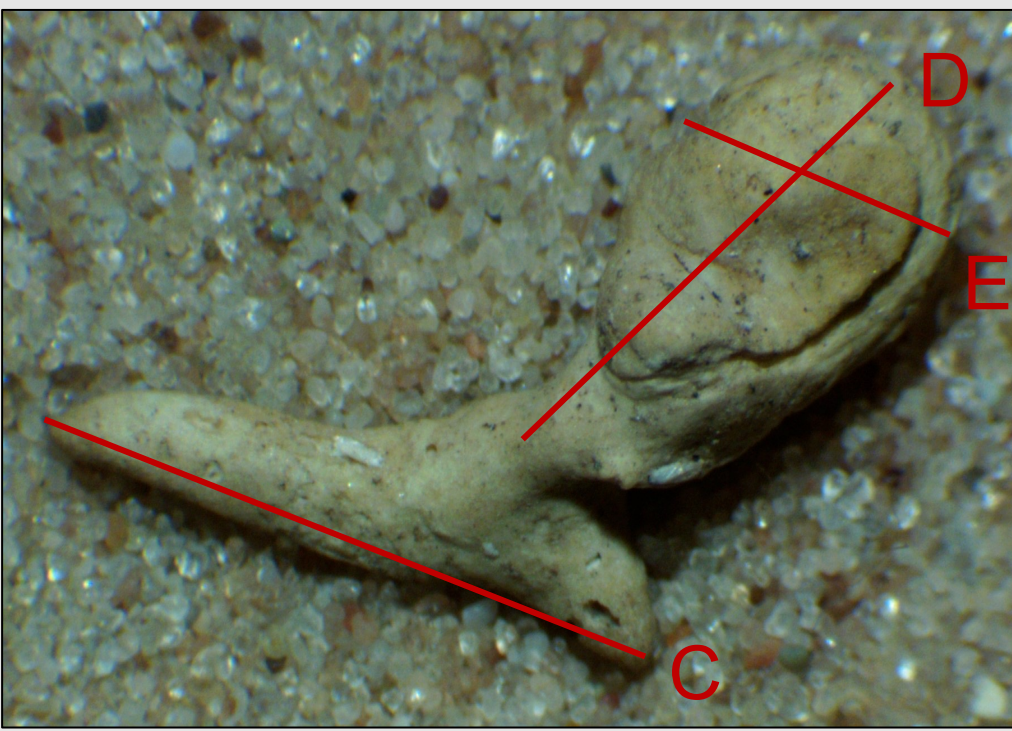
Burial rites (e.g. stone-lined graves, E-W orientation) in keeping with a Christian tradition



SK787 INCUS



SK787 MALLEUS



METHODS

- 29 ear ossicles (Incus and Malleus)
- Microscopic images taken using Leica S9i light microscope
- Scanned using Artec 3D Micro Scanner and turned into 3D models using Artec Studio Software
- 2 Incus and 3 Malleus standard dimensions ^[1,2] measured using line tools in ImageJ for microscopic images and MeshLab for 3D images

DATA ANALYSIS

- Mean, minimum absolute and maximum absolute differences
- Technical Error of Measurement (TEM), Relative TEM (rTEM), and coefficient of reliability (R) evaluate the level of agreement between methods ^[3]
- Intraclass Correlation Coefficient (ICC) measures reliability between methods

RESULTS

Bone Type	Dimension	Mean Difference (mm)	Min Absolute Difference (mm)	Max Absolute Difference (mm)	TEM (mm)	rTEM (%)	R
Incus	Total Length (A)	0.214	0.008	0.379	0.099	1.56	0.952
	Total Width (B)	0.100	0.006	0.550	0.122	2.38	0.839
Malleus	Length of Manubrium (C)	0.015	0.020	-0.365	0.131	2.89	0.842
	Length of Head and Neck (D)	0.068	0.019	0.445	0.130	3.34	0.816
	Width of the head in the axial section (E)	0.049	0.001	0.167	0.054	2.24	0.838

Bone Type	Measurement	ICC	95% CI	Reliability
Incus	Total Length	0.851	0.012, 0.963	Good
	Total Width	0.799	0.489, 0.922	
Malleus	Length of Manubrium	0.840	0.432, 0.962	
	Length of Head and Neck	0.790	0.478, 0.937	
	Width of the head in the axial section	0.796	0.346, 0.945	

DISCUSSION

3D models of ear ossicles, specifically incii and mallei, do provide an accurate representation albeit variable between ossicles and dimensions

To meet acceptable anthropological error standards, rTEM values should be ≤5%, which was met by all the dimensions in this study, and/or R values should be ≥0.95, which was only met by Incus Total Length ^[3]

Modern studies of ear ossicle morphometry have assisted with surgical interventions, but their use in investigating the health of past populations has yet to be fully explored ^[1, 4]

Ear ossicles generally survive well in archaeological skeletons and are ideal bones for ancient DNA and isotope analysis, but both are destructive processes ^[5, 6]

Accurate 3D representation of a skeleton's ear ossicles could permit further research after their destruction, damage, or loss, providing data suitable for a range of future studies (e.g., geometric morphometrics and comparisons between populations) ^[7]

Our future work will improve resolution of landmarks and features, and compare 3D models produced by a 3D scanner to physical ear ossicles and models produced from photogrammetry images to determine the most accurate method for further research

References
[1] Kumar, DV., et al. (2018). *J. Anat. Soc. India*, 67: 12-17; [2] Jain, S., et al. (2022). *Cureus* 14: e22410; [3] Shanley, C., Obertová, Z., Franklin, D. (2024). *For. Sci. Int.* 361: 112138; [4] Krenz-Niedbala, M., et al. (2021). *Anat. Rec.* 305: 1947-1961; [5] Sirak, K., et al. (2020). *Genome Res.* 30: 427-436; [6] Scheuer, L., Black, S. (2000). *Developmental Juvenile Osteology*; [7] Nossios, G., et al. (2016). *J. Clin. Med. Res.* 8: 76-83.

Acknowledgements
Thanks to: Ken Murphy and Archaeoleg Dyfed/Heneb; Cadw; Arfordir Penfro; Nineveh Charitable Trust; Cambrian Archaeological Association; all the volunteers who helped during the excavation and those who have supported other aspects of the project to date. Equipment was funded through an AHRC 'CapCo' grant awarded to K.A. Hemer (Ref: AH/V011529/1)
Email: jennifer.wilburn.23@ucl.ac.uk / k.hemer@ucl.ac.uk

