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Getting to grips with 3D printed bones: Using 3D models as 'diagrams' to improve accessibility of palaeopathological data

Stephanie Evelyn-Wright, Alex Dickinson and Sonia Zakrzewski

Abstract: This short report details a sub-project of 'Stories through Skeletons' an interdisciplinary venture undertaken by the Osteoarchaeology and Bioengineering departments at the University of Southampton. As part of this project, the team has been exploring the potential of using 3D printing technology to improve accessibility of palaeopathological data to a wider audience, through the production of tactile aids. To test this idea, models were created of Langer type mesomelic dwarfism exhibited in a skeleton from the Romano-British cemetery site of Alington Avenue, Dorset, UK. The 3D models were used as props during osteoarchaeology conference presentations and have proved useful to visually impaired and non-disabled audiences alike. Methods used to create the 3D models and the feedback received from the preliminary showing of the models at conferences are outlined, including the development of the idea of the 3D models as 'diagrams'. This highlights the creation of accessibility tools as another potential use of 3D technology in the field of osteoarchaeology and in so doing, adds the issue of accessibility to the ethical debates surrounding the use of 3D modelling technology in physical anthropology more broadly.

Keywords: 3D modelling, palaeopathology, accessibility, visual impairment, haptic models

Introduction

A recent project aimed to improve the accessibility of osteoarchaeological research through the use of 3D modelling technology and the associated production of tangible cognitive aids, in particular for people with visual impairments. This paper highlights the creation of these accessibility tools as another potential use of 3D modelling technology in the fields of biological anthropology and, more specifically, bioarchaeology and osteoarchaeology. The ethics surrounding the use of 3D modelling technology in studies of human skeletal remains has been the subject of recent debate (see Errickson et al. 2017; Hassett 2018; Hirst et al. 2018; Ulguim 2018 and other contributions in this volume), often focusing on issues surrounding the creation, curation and dissemination of 3D modelled and printed human bones, asking questions such as: who owns 3D models of human bones? Should 3D models of bones be open access or do researchers have a responsibility to monitor how they are used? By adding to this discussion, this paper aims to add issues of accessibility of osteoarchaeological research to the ethical debate within this wider publication.

The use of 3D model replicas of artefacts as tangible aids for people with visual impairments within the heritage sector is not new or especially unique (e.g. Jafri and Ali 2015; Neumüller et al. 2014; Oouchi et al. 2010; Themistocleous et al. 2016). These examples, however, are intended to be used in museum or art gallery settings and most have replicated man-made artefacts and art works. The replication of organic shapes, textures and internal biological structures present different challenges particularly due to their highly variable shape, texture and size, presenting complicated surfaces to scan and replicate (Allard et al. 2005; Errickson et al. 2017). The idea for this project came after the first author spoke at an interdisciplinary conference about research which involves the study of impairment and disability through analysis of ancient skeletal remains. Amongst the conference attendees, there were people with visual impairments who requested that any visual aids used were verbally described, including photographs of skeletal remains. The challenge of describing the palaeopathological differences of these skeletal remains to a non-specialist audience in a time efficient manner was extreme, especially when the bones being described form just one part of the story. In order to address this challenge at future conferences, an interdisciplinary team was formed, comprising of members from the Archaeology and Bioengineering departments at the University of Southampton. The aim was to determine if 3D printed replicas of an example palaeopathological specimen could be created to evaluate their potential as tangible comprehension aids for people with visual impairments. This experiment was undertaken as part of the 'Stories from Bones' project, which develops outreach and research projects that utilise 3D scanning and biomechanical modelling techniques to address osteoarchaeological questions (Stories from Bones nd).

Case study and methods

The bones that were 3D scanned were from a young adult female from the Roman cemetery site of Alington Avenue, just outside Dorchester in Dorset, UK. Individual AA766 was a young adult female who lived c. 3rd-4th century AD. She exhibited a rare form of dwarfism called Langer type Mesomelia (Davies et al. 2002). This is a disproportionate form of dwarfism which affects the radii, ulnae, tibiae and fibulae more pronouncedly than the humeri and femora, as can be seen in figure 1 (Baxova et al. 1994; Langer 1967; Spranger et al. 2012). This form of dwarfism is also linked with other morphological differences such as Madelung's deformity and a hypoplastic mandible (Langer 1967; Spranger et al. 2012). This case study presents a

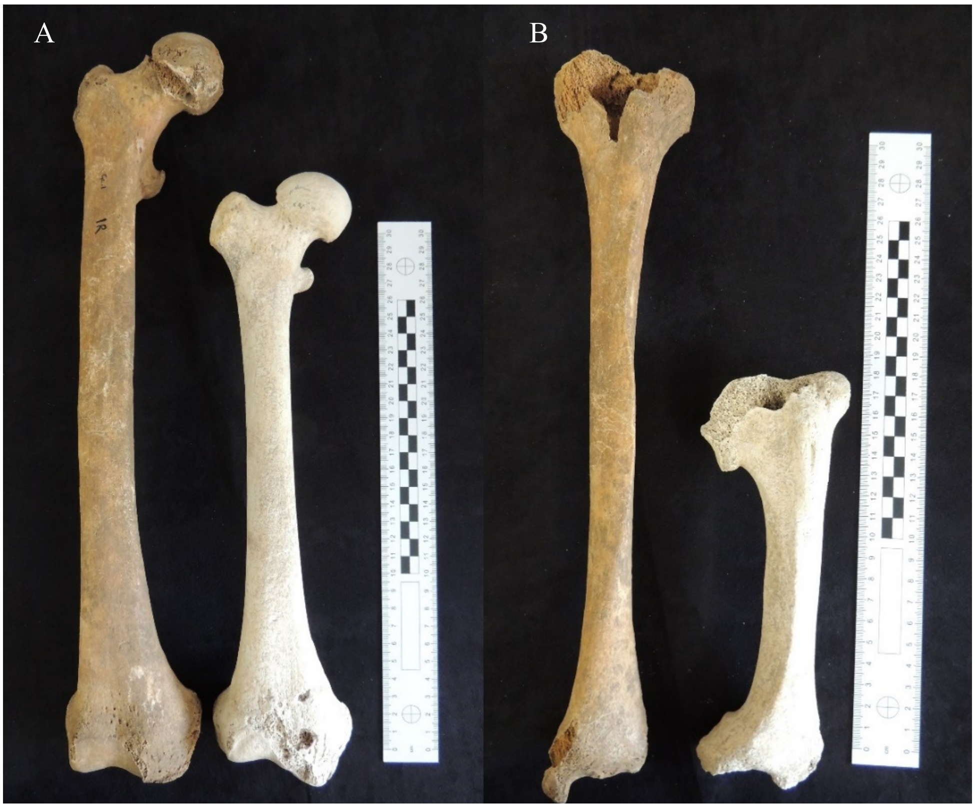

Figure 1: Anterior views of right side femora (A) and tibiae (B) from AA766 and another adult female (Great Chesterford 1)(©Evelyn-Wright 2017)

relatively unusual opportunity for bioarchaeological explanation and exploration, as the developmental timeline of the clinical condition is relatively well understood (Langer 1967), and this can be mapped onto the expected life course of the individual. Such an approach has been developed into an osteobiography and has become a key part of the wider research project, exploring the potential consequences of such a condition on the experience of the individual within a Romano-British context (Evelyn-Wright 2019).

The left long bones were selected to be scanned (i.e. humerus, radius, ulna, femur, tibia and fibula). The bones' external surfaces initially digitised using a structured white light scanner (Go!SCAN, Creaform Inc, Canada), and scans were processed in MeshLab 2016.12 (CNR, Italy). The models were printed in one colour (white) acrylic plastic using an UP BOX printer. The models produced are full sized; this was key as it was thought that users might well want to compare them to their own bodies.

The models have been shown at numerous events, both focused at academic and non-academic audiences, as an aid for the communication of the wider research questions, approaches and results. At two events, the author was fortunate enough to speak to audiences that included people with visual impairments who not only engaged with the 3D models but were also kind enough to offer feedback. The first was the "Taking Stock: the 3rd Disability History Conference" at the London Metropolitan Archives in November 2017, and the second was at the Vari/Abilities IV conference held at the University of London in June 2018. The feedback obtained from these two events that forms the focus of the rest of this paper.

Resulting Feedback

The keynote speaker at 'Taking Stock: the 3rd Disability History Conference' was the former British Home Secretary, Lord David Blunkett, who has been blind since birth. He examined the models and commented on their helpfulness to his understanding of the stories of disability being described. Lord Blunkett (pers comms) was kind enough to offer the following comment: "[he] felt that a tactile approach of this sort enhanced the understanding and emotional engagement with the artefacts and felt that this kind of approach could be adopted more widely".

One half of the organisation team of Vari/Abilities IV was Professor Chris Mounsey. Professor Mounsey's experience of visual impairment differs greatly from Lord Blunkett's, having acquired his partial sight impairment later in life, and therefore their experience and usage of tactile tools, such as braille, differ. Lord Blunkett is a frequent reader and writer of braille. In an article he wrote on his own use of Braille since the age of 4, he describes the need to develop sensitive fingertips (Blunkett 2009). Professor Mounsey on the other hand describes Braille as 'just dots

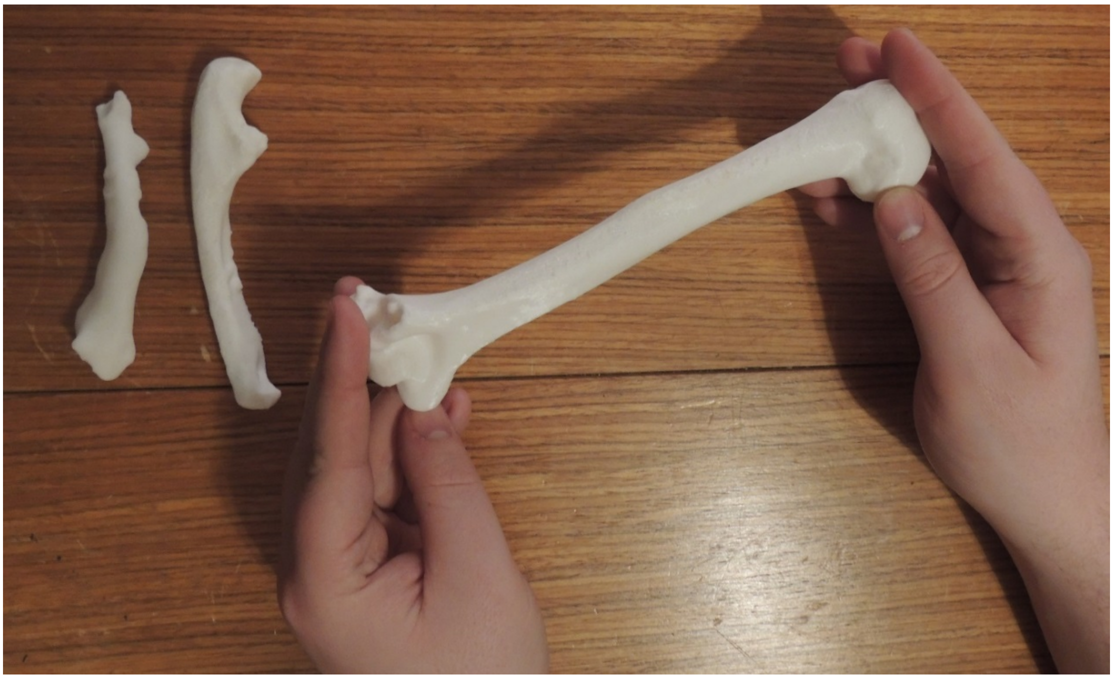

Figure 2: 3D diagram of left side humerus of AA766 being handled (©Evelyn-Wright 2019)

on a page', which he cannot discern. Given these insights, it was questioned whether tactile models of this nature would be as useful for someone with acquired visual impairment. Professor Mounsey explained that he uses touch to access the world and that the 3D models helped him understand the human remains under consideration and allowed him to access the data in a similar way he accesses most other things. He, however, also stated that he needed more time to 'get to grips' with the models and required guidance as to what to feel for. This request for direction has been previously reported for the use of 3D models by the visually impaired (Neumüller et al. 2014). He also wanted a model of a life size normative bone to feel alongside the atypical in order to facilitate comparison. Professor Mounsey (pers comms) commented

> "…I definitely think these things are helpful because of, as I said, the ways of accessing the world, the plenum, the empirical plenum of someone who can't see properly is different from someone who can see properly and so give them absolutely every possibility of understanding what it is your doing."

It is worth noting that although the target audience for the models were people with visual impairments, other audience members also were keen to see and feel the models too. Dr Stan Booth, the second half of the organisation committee of Vari/Abilities IV, commented that the 3D models were far more effective at revealing the diminutive scale of AA766's arm bones than the photographs on the presentation slide, even with normative bones or scales depicted alongside for scale. It appears, therefore, that 3D models can help improve accessibility and communication of osteoarchaeological material to people both with and without visual impairments.

Discussion

The 3D printed replicas have distinct advantages over the real bones in the context of conference handling, not least in their comparatively easy transportability and their replaceability. Furthermore, it is likely that, for most people, handling plastic replicas provides less of a potential moral dilemma than touching the real remains. 3D printed replicas are also invaluable in cases, such as with AA766, when the remains are only temporarily loaned. The increasing availability of the technology means such usage at conferences and in museums displays and/or other events is more possible and indeed has been actively encouraged by the people encountered so far.

The differences in surface texture could provide a challenge in further application in osteoarchaeology. A drawback of the scanning process is the limited spatial resolution of 0.5mm, which is inadequate to capture sub-millimetre scale bony features and textures, and which could thus affect the efficacy of 3D models to represent other palaeopathological case studies. For example, periosteal new bone growth, such as resulting from infection, could be difficult to replicate and detect as such lesions typically involve slight changes in texture that are difficult to spot when initially studying human remains, and thus would be even more difficult for the inexperienced observer to discern. Sub-millimetre spatial resolution volume imaging has been conducted subsequently using microfocus computed tomography scanning (μCT) which will enable finer surface details to be replicated in the 3D model, and with enhanced printing technology these details may be represented in a future set of replicas.

In the case study presented, the technology was found to represent the morphological changes well. Professor Mounsey (pers comms) suggested that models be described as '3D diagrams', reinforcing the idea that the 3D models are physical representations of figures. Instead of trying to replicate the bones accurately in every way, the bones are representations designed to better communicate key morphological information. This designation of 3D replicas as diagrams is helpful as it changes the emphasis of the models to the audience; instead of being just accurate replicas, they are designed to illustrate a point, like any image in a presentation.

Ultimately, this report is based on the qualitative feedback of just a few users. More demonstration, testing and experimentation needs to be undertaken to test the efficacy of 3D modelling technology at a) representing different examples of palaeopathology and b) communicating palaeopathological information to a wider range of people with visual impairments. It is hoped that this report has highlighted the potential additional use of 3D printing in physical anthropology and will inspire further research and development. It is also hoped that the use of 3D models as tangible aids for people with visual impairments is added to the ethical considerations, surrounding particularly the availability and dissemination of 3D scans of osteoarchaeological material. 3D printing technology has the potential to help improve the accessibility of the physical anthropological and osteoarchaeological disciplines. Professor Mounsey (pers comms) argues that, the hyper sensitive finger tips developed by particularly people who use braille, who can pick up the slightest differences in surface textures, would be a valuable asset to osteological analysis. Their insight is currently underutilised in the study of human remains, most likely due to the inaccessibility of the discipline, perhaps the use of

3D models during conference talks or outreach events, can help the discipline engage with these individuals.

Conclusion

3D printed diagrams can provide a helpful tool with which to communicate palaeopathological information, particularly morphological information, to people with visual impairments. The concept of 3D models as diagrams, is especially valuable as it takes the onerous off the requirement the need to replicate material as accurately as possible and instead places emphasis on the objects as stylised tools to communicate specific information. Accessibility is a key ethical issue which the fields of biological anthropology and osteoarchaeology, and academia more broadly, struggle to deal with. The use of 3D printed replicas of human remains therefore presents a step in the right direction towards improving accessibility and communication of the discipline.

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References

Allard, T T, Sitchon, M L, Sawatzky, R & Hoppa, R D. 2005. Use of hand-held laser scanning and 3D printing for creation of a museum exhibit. In: Mudge, M, Ryan, N & Scopigno, R (eds.). *Proceedings of 6th International Symposium on Virtual*

Reality, Archaeology and Cultural Heritage VAST2005: Short and Project Papers 2005. pp. 97-101.

Baxova, A, Kozlowski, K, Netriova, I & Sillence, D. 1994. Mesomelic dysplasia: Langer type. *Australasian Radiology*. 38. pp. 58-60. https://doi.org/10.1111/j.1440-1673.1994.tb00128.x.

Blunkett, D. 2009. Why Braille is brilliant. *BBC News Magazine* [online], 2nd January 2009. Available at: <http://news.bbc.co.uk/1/hi/magazine/7807217.stm> [Last accessed 12th February 2019].

Davies, S M, Bellamy, P S, Allen, M J & Woodward, P J. (eds.) 2002. *Excavations at Alington Avenue, Fordington, Dorchester, Dorset 1984-87*. Dorchester: Dorset Natural History and Archaeological Society.

Errickson, D, Grueso, I, Griffith, S, Setchell, J, Thompson, T J U, Thompson, C E L & Gowland, R L. 2017. Towards a best practice for the use of active non-contact surface scanning to record human skeletal remains from archaeological contexts. *International journal of osteoarchaeology*. Vol 27 (4). pp. 650-661. https://doi.org/10.1002/oa.2587.

Evelyn-Wright, S. 2019. Dis/ability in Roman Dorset – an integrated osteobiography approach. In: Mounsey, C & Booth, S (eds.). *Bodies of Information: Reading the Variable Body from Roman Britain to Hip Hop*. New York: Routledge.

Hassett, B. 2018. Which Bone to Pick: Creation, Curation, and Dissemination of Online 3D Digital Bioarchaeological Data. *Archaeologies: Journal of the World Archaeological Congress*. Vol 14 (2) pp. 231-249. https://doi.org/10.1007/s11759-018-9344-z.

Hirst, C S, White, S & Smith, S E. 2018. Standardisation in 3D Geometric Morphometrics: Ethics, Ownership, and Models. *Archaeologies*. Vol 14 (2) pp. 272-298. https://doi.org/10.1007/s11759-018-9349-7.

Jafri, R & Ali, S A. 2015. Utilising 3D printing assist the blind. *2015 international conference on health informatics and medical systems*. pp. 55-61.

Langer, L .1967. Mesomelic dwarfism of the hypoplastic ulna, fibula, mandible type. *Radiology*. 89 (4). pp. 654-660. https://doi.org/10.1148/89.4.654.

Neumüller, M, Reichinger, A, Rist, F & Kern, C 2014. 3D Printing for Cultural Heritage: Preservation, Accessibility, Research and Education. In: Ioannides, M & Quak, E (eds.). *3D Research Challenges*. Berlin: Springer-Verlag. pp. 119-134. https://doi.org/10.1007/978-3-662-44630-0_9.

Oouchi, S, Yamazawa, K & Secchi, L. 2010. Reproduction of Tactile Paintings for Visual Impairments Utilized Three-Dimensional Modeling System and the

Effect of Difference in the Painting Size on Tactile Perception. In: Miesenberger K, Klaus J, Zagler W & Karshmer A (eds.). *Computers Helping People with Special Needs. ICCHP 2010*. Vol 6180. Berlin: Springer-Verlag. pp. 523-526. https://doi.org/10.1007/978-3-642-14100-3_79.

Spranger, J W, Brill, P W, Nishimura, G, Superti-Furga, A & Unger, S. 2012. *Bone Dysplasias: An Atlas of Genetic Disorders of Skeletal Development*. 3rd edition. Oxford: Oxford University Press.

Stories from Bones nd. *Stories from Bones: A collaborative outreach initiative between the departments of Engineering and Osteoarchaeology at the University of Southampton*. <http://generic.wordpress.soton.ac.uk/storiesfrombones/> [Last accessed 21st May 2019].

Themistocleous, K, Agapiou, A & Hadjimitsis, D. 2016. Experiencing Cultural Heritage Sites Using 3D Modeling for the Visually Impaired. *Procedures of Euromed 2016: Digital Heritage, Progress in Cultural Heritage: Documentation, Preservation, and Protection, Lecture Notes in Computer Science*. Vol 10059. pp. 171-177. https://doi.org/10.1007/978-3-319-48974-2_19.

Ulguim, P. 2018. Models and Metadata: The ethics of sharing bioarchaeological 3D models online. *Archaeologies: Journal of the World Archaeological Congress*. Vol 14 (2) pp. 189-228. https://doi.org/10.1007/s11759-018-9346-x.