**A black and white logo

Description automatically generatedUNDERGRADUATE SUMMER VACATION SCHOLARSHIP AWARDS – FINAL SUMMARY REPORT FORM 2022/23**

***NB: This whole report will be posted on the Society’s website therefore authors should NOT include sensitive material or data that they do not want disclosed at this time.***

**Name of student:** Solomon Page Godfrey

Twitter Handle\*: @solpg\_712

*(\*optional)*

**Name of supervisor(s):**

Dr Eilidh Ferguson @Ferguson\_Eilidh

Dr Caroline Allen @Carolinemallen2

**Project Title: (no more than 220 characters)**

Tactile Anatomy: Improving access to hands-on learning for craniofacial growth and development.

**Project aims: (no more than 700 words)**

The creation of 3D printed artefacts to support teaching is seen most frequently in anatomical education (1). Indeed, a growing body of literary evidence, from multiple anatomical disciplines, supports the notion that 3D printed models enhance student learning experience and exam performance (1,2). Some of the potential benefits of using 3D printed models for anatomical teaching include increased durability for student handling, reduced costs, reproducibility to support large class sizes, and mobility/versatility (3).

The study of craniofacial growth and development is one area of anatomical education which could benefit from the inclusion of 3D printed models. Not only are structures complex and change over time, but a lack of juvenile skeletal teaching collections limits student access to real specimens. Due to the fragile nature of these specimens, preservation is of paramount importance and demands minimal handling (4). As such, when collections exist, students can often observe but not physically handle the specimens. Anatomy, however, is widely regarded as a 3D subject, whereby tactile exposure enhances understanding of complex anatomical structures (2). 3D printed models, therefore, represent a viable option to overcome barriers to “hands on” teaching of delicate juvenile specimens. As such, the purpose of our study was to create accurate 3D printed models of juvenile skulls and investigate their viability as an educational resource in teaching craniofacial development.

Aims/Objectives

1: To create three physical 3D prints of juvenile skulls at various

2: To assess the metric and morphological accuracy of the 3D prints.

3: To evaluate the educational value of the 3D prints in teaching, through consultation with anatomy educators.

4: To investigate the potential learning benefits of using 3D prints vs real anatomical specimens in teaching craniofacial growth and development.

**Project Outcomes and Experience Gained by the Student (no more than 700 words)**

1: To create three physical 3D prints of juvenile skulls at multiple stages of development.

Three juvenile skulls at various stages of development were selected from the University of Glasgow anatomical collection. Surface data was acquired for each specimen, using an Artec Space Spider 3D scanner, and processed in Artec Studio 17 to generate digital 3D models. A Flash Forge Adventurer 4 3D printer was used to create physical prints for each of the three skulls.

2: To assess the metric and morphological accuracy of the 3D prints.

**Morphological analysis**

The 3D prints were initially inspected for any obvious structural defects with nothing significant identified. Cranial features, assessed on each of the real skulls and their 3D printed models, were categorized as either well defined, poorly defined, or absent based on their morphology.

Most features on the real specimens were equivalently categorized on the 3D printed models, evidencing a high degree of morphological accuracy. When observed, inaccuracies in the 3D prints were restricted to cranial openings such as the infraorbital foramen and foramen magnum and optic canal, which were often occluded and present as depressions. Additionally, the most lateral aspect of the parietal eminence was either absent or poorly defined unilaterally on each 3D print, which related directly to its positioning on the print bed.

**Metric Analysis**

Seventeen craniometric measurements were chosen to assess the accuracy of the 3D prints. Each measurement was taken on both the digital and 3D printed models for all three skulls. The real skulls were not analyzed due to their fragility. Measurements were statistically interrogated with R studio using Wilcoxon signed rank test. No significant differences in cranial dimensions were observed between the digital and 3D models for any of the juvenile skulls, evidencing a high degree of metric accuracy in 3D printing.

3: To evaluate the educational value of the 3D prints in teaching, through consultation with anatomy educators.

Anatomy educators (n=4) at the University of Glasgow were invited to inspect both the real skulls and the 3D printed models in turn. For each modality, they completed a short feedback survey covering resource quality and potential teaching applications. Overall, educators supported the use of the 3D printed models in teaching and reported a good level of anatomical accuracy. Educators valued the tactile feel and robustness provided by the 3D printed models.

4: To investigate the potential learning benefits of using 3D prints vs real anatomical specimens in teaching craniofacial growth and development.

University students (n=4) with anatomy as a core component of their degree were invited to take part in a short, group-based learning exercise which combined the 3D printed models (viewing and handling) and real specimens (viewing only) with a 2D textbook style teaching resource developed as part of this project. Semi-quantitative and qualitative data on learning experience was collected via evaluation surveys and a focus group, respectively. The latter was subject to inductive semantic thematic analysis in line with Braun and Clarke (5) to identify key themes.

Overall, responses to using the 3D printed models were positive. Participants enjoyed using the models and thought they were a valuable educational resource which they would like to use in future lab sessions. Tactile learning benefits and a combined learning approach were common themes identified from focus group data.

Experience

Throughout the project, I have developed a strong theoretical understanding of craniofacial development and educational research design, including the importance of research ethics. I am now more able to reflect on the ethical implications of my actions and appreciate the necessity of addressing historical ethical concerns in modern research. I have enjoyed collaborating with colleagues and have gained considerable experience in data collection and analysis using excel and R studio statistical software. Full training using handheld 3D scanners, 3D printers and digital modelling software, has equipped me with a range of practical skills and knowledge applicable to a wide array of advancing anatomical fields. Aspects of the project were challenging. For example, unfamiliar concepts of qualitative research and thematic analysis were daunting at first, however, with perseverance, effective communication, and teamwork I was able to grasp theories and produce effective analysis. These key attributes will benefit my honors project, postgraduate study, and future career.

**Please state which Society Winter or Summer Meeting the student is intending to present his/her poster at: ￼**

Anatomical Society Winter Meeting January 2024

**Proposed Poster Submission Details (within 12 months of the completion of the project) for an AS Winter/ Summer Meeting – (no more than 300 words) ￼**

Due to the fragile and irreplaceable nature of juvenile cranial specimens, students are often restricted to a visual inspection when learning craniofacial development. Anatomy, however, is a 3D subject and students benefit from tactile interactions. The use of 3D printed technology in anatomical education is gaining traction, and 3D printed models represent a viable option to overcome barriers to “hands on” learning. As such, this study aimed to create accurate 3D printed models of juvenile skulls and investigate their relative educational value in teaching craniofacial development. Digital models of three juvenile skulls, at various developmental stages, were generated from surface scan data and 3D printed. Accuracy of the 3D prints was assessed through morphological analysis of key anatomical features against the digital models, and metric analysis of cranial dimensions against the real skulls. The relative educational value of the 3D prints was investigated through consultation with anatomical educators, and survey/focus group feedback from a mixed modality student learning session. No significant differences in cranial dimensions were observed between the 3D prints and digital models, and only limited discrepancies in landmark morphology were identified between the 3D prints and real skulls. Educators supported the use of the 3D prints in teaching and reported a good level of model accuracy; students enjoyed using the 3D prints and valued them as an educational resource. Five key themes were identified from thematic analysis of focus group data: tactile benefits, accuracy, accessibility, combined learning, and emotional experience. In conclusion, accurate models of juvenile cranial specimens, with subjective educational value, can be produced with accessible 3D printing technology. Whilst these models may represent a viable alternative, or adjuvant, to real anatomical specimens for teaching craniofacial development, further investigation with a larger and more representative student sample is required to substantiate these preliminary findings.

**Brief Resume of your Project’s outcomes**: **(no more than 200-250 words)**.

*The title of your project and a brief 200–250-word description of the proposed/completed project. The description should include sufficient detail to be of general interest to a broad readership including scientists and non-specialists. Please also try to include 1-2 graphical images (minimum 75dpi). NB: Authors should NOT include sensitive material or data that they do not want disclosed at this time.*

Due to the fragile and invaluable nature of juvenile skull collections, the study of craniofacial development is often restricted to observational inspection that limits tactile exposure. 3D printed models offer an alternative educational resource which could overcome barriers to “hands on” learning. Indeed, the use of 3D printed artefacts in anatomical education is gaining traction and is supported by a growing body of evidence (1,2). The purpose of this study was to create accurate 3D printed models of juvenile skulls and evaluate their relative educational value in teaching craniofacial development.

Digital and 3D-printed models were created from three juvenile skulls at various developmental stages. To assess the 3D prints accuracy, cranial measurements and feature morphology were compared to the digital models and real skulls, respectively. No significant metric differences were identified, with minimal morphology discrepancies, demonstrating the high fidelity of the 3D printed models.

The educational value of the 3D prints compared to the real skulls was assessed through staff consultation and student surveys/focus group. Educators supported the use of 3D prints in teaching and valued their tactile feel and robustness, whilst students enjoyed using the 3D prints and believed they were a valuable educational resource. Tactile learning benefits and a combined learning approach were common themes identified from the focus group.

In conclusion, 3D printed models may represent an alternative or adjuvant to real specimens for teaching craniofacial development, however, further investigation with a larger and more representative student sample is required to further support these findings.

**Other comments: (no more than 300 words)**

References

1. Ford, S. and Minshall, T. (2019). Invited review article: Where and how 3D printing is used in teaching and education. *Additive Manufacturing*, 24(25), pp.131-150. DOI: 10.1016/j.addma.2018.10.028

2. Salazar, D., Thompson, M., Rosen, A. and Zuniga, J. (2022). Using 3D Printing to Improve Student Education of Complex Anatomy: a Systematic Review and Meta-analysis. *Medical Science Educator*, 32(5). DOI: 10.1007/s40670-022-01595-w

3. McMenamin, P.G., Quayle, M.R., McHenry, C.R. and Adams, J.W. (2014). The production of anatomical teaching resources using three-dimensional (3D) printing technology. *Anatomical Sciences Education*, 7(6), pp.479-486. DOI: 10.1002/ase.1475

4. Khayruddeen, L., D. Livingstone and E.Ferguson (2019). Creating a 3D learning tool for the growth and development of the craniofacial skeleton. *Biomedical Visualisation.* 2, pp5.7-70. DOI: [10.1007/978-3-030-14227-8\_5](https://doi.org/10.1007/978-3-030-14227-8_5)

5. Braun, V. & Clarke, Victoria (Associate Professor in Sexuality Studies) (2022). Thematic analysis: a practical guide. *SAGE Publications Ltd.* London.

|  |
| --- |
| **Data Protection/GDPR**: I consent to the data included in this submission being collected, processed and stored by the Anatomical Society. Answer YES or NO in the Box below |
| Yes |
| **Graphical Images**: If you include graphical images you must obtain consent from people appearing in any photos and confirm that you have consent. A consent statement from you must accompany each report if relevant. A short narrative should accompany the image. Answer N/A not applicable, YES or NO in the box below |
| N/A |
| **Copyright**: If you submit images you must either own the copyright to the image or have gained the explicit permission of the copyright holder for the image to be submitted as part of the report for upload to the Society’s website, Newsletter, social media and so forth. A copyright statement must accompany each report if relevant. Answer N/A not applicable, YES or NO in the box below |
| N/A |

*Signature of student........Solomon Page-Godfrey...........Date 26/09/2023*

*Signature of supervisor…………Eilidh Ferguson………….......... Date…30.09.23……….…*

END OF FORM

----------------------------------------------------------------------------------------------------------------------------------------

*File: USVRS FINAL SUMMARY REPORT – EF SPG Website version uploaded 031023*