A 3D Printed Osteological Collection and its Role in Health Professions Education: A Case Report from Macquarie University, Sydney

Goran Štrkalj[1,2], Manisha Dayal[3]

[1] Department of Chiropractic, Macquarie University, Sydney, New South Wales, Australia
[2] Department of Anatomy, The University of New South Wales, Sydney, New South Wales, Australia
[3] School of Science and Health, Western Sydney University, Campbelltown, New South Wales, Australia
Contact email: gstrkalj63@gmail.com; Telephone: +61 (0)2 9850 6197

Abstract: 3D printing is one of the technological advancements that has application in health sciences education. At Macquarie University it has been used for the printing of bones which are then utilized in teaching anatomy. Assessment of accuracy suggest that these prints are accurate copies of the real bones. As such, 3D prints preserve anatomical variation and pathologies, rarely present in commercially produced anatomical models. The bone collection is currently being enlarged and it is planned that the soft tissue and microscopic structures will be printed soon. It is also envisaged that 3D prints will be used in subjects other than anatomy.
[Štrkalj G, Dayal M. **A 3D Printed Osteological Collection and its Role in Health Professions Education: A Case Report from Macquarie University, Sydney.** *Life Sci J* 2019;16(6):69-72]. ISSN: 1097-8135 (Print) / ISSN: 2372-613X (Online). http://www.lifesciencesite.com. 11. doi:10.7537/marslsj160619.11.

Keywords: 3D printing, health professions education, bones, anatomy

1. Introduction

Modern clinical practice and research have become strongly reliant on technological advancements and health professions education has followed this trend (Harden et al., 2018). One of the new technologies that has been making a strong impact in education is 3D printing, also known as rapid prototyping or additive manufacturing. This is a digitally directed layer-by-layer material deposition manufacturing process (Lantada and Morgado, 2012). It would appear that 3D printing has been particularly valuable in the areas in which visualizing structures in three dimensions is important, in disciplines such as anatomy, radiology as well as manual therapy and surgical disciplines. Several studies have already demonstrated that accurate 3D prints of various body structures can be made with considerable accuracy, even on consumer grade desktop printers. It has also been shown that and 3D printed anatomical models are a valuable teaching resource both in terms of students' satisfaction and in achieving learning outcomes (Baskaran et al., 2016; Li et al., 2017; Langridge et al., 2018).

This paper focuses on the Macquarie University collection of 3D printed bony elements and outlines the rationale for its creation (including advantages of the prints over other resources), process of production, role in education and plans for the future. In health professions education (including, chiropractic, medical science, pre-physiotherapy and pre-medicine degrees) these 3D printed bones have so far been used mainly in anatomy, while the actual process of printing has value in the development of students' research skills as well as in the continual professional development of anatomy tutors (Štrkalj et al., 2012).

2. Case report

There is a general agreement among anatomy educators that real human tissue is the most valuable resource in teaching and learning about the structures of the human body (Pather, 2015). In learning gross anatomy, whether through dissection or the study of prosected specimens, cadavers still present the main educational resource. However, human tissue is not always easy to acquire and maintain for the laboratory usage. At Macquarie University a sufficient number of prosected bodies and body parts has been regularly acquired, enabling efficient delivery in gross anatomy. On the other hand, University does not have a facility for the preparation of bones and has to rely on the existing collection of human skeletons. While this collection is not very large it is big and diverse (in terms of biological variation and pathologies) enough for effective anatomy teaching (Danilovic et al., 2013). However, even if the necessary care is applied during anatomy laboratory sessions, damage to the bones is difficult to avoid, especially when working with large groups of students. This damage, however, can be considerably decreased through the use of alternatives to the real tissue.

While commercially produced anatomical models of bones are used for this purpose, these models, even the high-quality ones, are rather schematic and do not show anatomical variation essential in teaching anatomy (Bergman, 2011; Štrkalj et al., 2011). 3D printing, on the other hand, enables production of models made upon the real bones,

showing both anatomical variation and pathologies (Fig. 1) (AbouHashem et al., 2015). As the material used in standard 3D printers is of low cost, once the infrastructure is in place 3D printed bones are acquired at a significantly lower cost than commercial anatomical models. Furthermore, just like the models, and unlike the real tissue, 3D prints can be used in any educational environment.

Figure 1. A 3D printed model of a lumbar vertebra showing osteophytic lipping.

The first step in the production of 3D printed models consisted of acquiring 3D images. At first scanning was carried out using the hand-held Artec Spider 3D surface scanner. The images obtained were transferred into the standard tessellation (.stl) file format. These were then used in printing on three different types of desktop 3D printers, Mojo, MakerBot Replicator 2 and Flashforge Creator Pro. The materials used were acrylonitrile butadiene styrene (ABS) thermoplastic polymer for the Mojo and biodegradable polylactic acid (PLA) for the MakerBot and Flashforge.

All stages of the process were carried out in collaboration with Western Sydney University with which Macquarie has established a fruitful community of practice in anatomy (Štrkalj and Dayal, 2014). This collaboration enabled a bigger database of bones, engagement of different scanning techniques and simultaneous printing on different printers at two institutions.

The first bones to be printed were vertebrae, primarily because they are irregular bones and it was hypothesized that if they can be created with sufficient accuracy it would be possible to create with at least equal accuracy bones of simpler shapes. Subsequently other bones have been produced. Furthermore, images have also been obtained from CT scans and transformed into a printable format (Fig. 2). The images obtained from the CT scans enable observation and printing of the various anatomical sections and observation of the inner surfaces of bones.

Once the bones were produced their accuracy was estimated using both qualitative and quantitative methods. Qualitatively, a visual observation was made by four anatomy lecturers. They were unanimous in their estimate that all important morphological features are clearly visible on the 3D printed bones, deeming them accurate for anatomy teaching. In quantitative approach, a battery of measurements was carried out in order to compare the prints with the "original" bones upon which they were produced. This test also corroborated the accuracy necessary for anatomy teaching as there were no significant differences between prints and bones in 96 out of 108 measurements (AbouHashem et al., in print). It generally confirmed the results of previous studies which suggested that inaccuracies generally happen only in very small structures (e.g., less than a millimeter) (McMenamin et al., 2014; Thomas et al., 2016).

Figure 2. A 3D printed model of a pelvis and proximal femora (image obtained from a CT scan).

Discussion

The 3D printed models of bones were used in anatomy laboratory sessions together with the real bones and models. Furthermore, obtained 3D images were imported into an interactive viewing portal which was in turn made available to students via a model based "iLearn" platform (Fig. 3). These images could be manipulated while being observed: moved, enlarged and looked at from different angles. These images were accessible to students outside the laboratory time, providing them with an opportunity to learn on the pseudo-three-dimensional representations of bones.

As new prints have been produced they have been constantly checked for accuracy. These assessments of accuracy have been turned into small osteometry based research projects in which health

professions students participate. At the same time ethical aspects of 3D printing (Cornwall, 2016) are also investigated (Alexander et al., 2014; AbouHashem et al., 2017). These projects aim at facilitating revision, reflection and deep learning of anatomy as well as developing and improving students' research skills (Štrkalj et al., 2013).

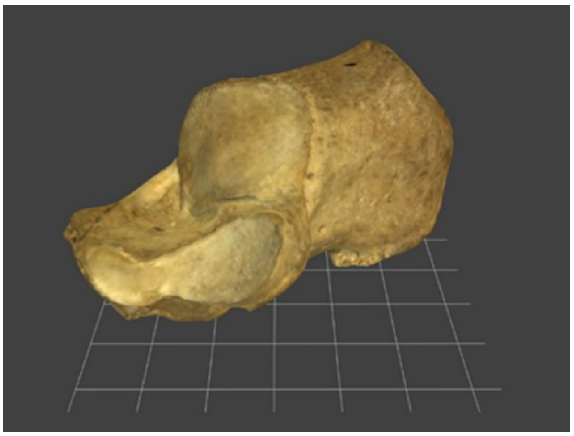

Figure 3. A screenshot of the interactive 3D image of a calcaneus.

The actual 3D printing is carried out by senior students and tutors in anatomy. For the latter, this activity (which also includes complex and technically demanding activities such as image analysis) is seen as part of their continuous professional development (Štrkalj et al, 2016).

While 3D prints and images are currently used mainly in gross anatomy it is envisaged that the prints of gross anatomical structures will be used in radiology and a number of clinical subjects. The most important aim is to increase the number of elements in the skeletal collection and commence with the printing of soft tissue structures. Furthermore, it is planned that 3D prints of microscopic structures will also be used in teaching cell biology and histology**.**

Conclusion

3D printing offers numerous opportunities in health professions education. At Macquarie University 3D prints are used as a valuable teaching resources in anatomy while the actual printing process (and activities around it) is used to assist health professions students in revising anatomy and developing research skills, and as part of continuous professional development for anatomy tutors. Furthermore, 3D printing related activities are ramifying and entering subjects other than anatomy.

Corresponding Author:
Prof Goran Štrkalj
Department of Chiropractic
Macquarie University
NSW 2109, Australia
Telephone: +61 (0)2 9850 6197
E-mail: gstrkalj63@gmail.com

References

1. Harden RM, Lilley P, McLaughlin J. Forty years of medical education through the eyes of Medical Teacher: From chrysalis to butterfly. Med. Teach. 2018;40: 328-330.
2. Lantada AD, Morgado PL. Rapid prototyping for biomedical engineering: Current capabilities and challenges. Annu. Rev. Biomed. Eng. 2012;14: 73-96.
3. Baskaran V, Štrkalj G, Štrkalj M, DiIeva A. Current applications and future perspectives of the use of 3D printing in anatomical training and neurosurgery. Front. Neuroanat. 2016;10: 69. doi: 10.3389/fnana.2016.00069.
4. Li K, Kui C, Lee E, Ho C, Wong S, Wu W, Wong W, Voll J, Li G, Liu T, Yan B, Chan J, Tse G, Keenan I. The role of 3D printing in anatomy education and surgical training: A narrative review. Med Ed Publish 2017;6: 11–19, 110–123.
5. Langridge B, Momin S, Coumbe B, Woin E, Griffin M, Butler P. Systematic review of the use of 3-dimensional printing in surgical teaching and assessment. J. Surg. Educ. 2018;75: 209-221.
6. Štrkalj G, Beirman R, Štrkalj M. Teaching anatomy to chiropractic students: Experiences from Macquarie University, Sydney, Explore J. Sci. Heal. 2012;8: 141-144.
7. Pather N. The pros and cons of dissection and prosection, In: Chan LK, W. Pawlina W, editors. Teaching anatomy: A practical guide. New York: Springer; 2015. p. 213-221.
8. Danilovic M, Hussein K, Jamal-Eddine W, Lam D, Matkovic P, Casey M, Serafin S, Štrkalj G. Anthropological analysis of the skeletal collection of the chiropractic department of Macquarie University. Clin. Anat. 2013;26: 643.
9. Bergman RA. Thoughts on human variations. Clin. Anat. 2011;24: 938–940.
10. Štrkalj G, Spocter MA, Wilkinson AT. Anatomy, medical education and human ancestral variation, Anat. Sci. Educ. 2011;4: 362-365.
11. Abou Hashem Y, Dayal M, Savanah S, Štrkalj G. The application of 3D printing in anatomy education. Med. Educ. Online. 2015;20: 29847.doi:https://doi.org/10.3402/meo.v20.29847
12. Štrkalj G, Dayal MR. Working together, sharing resources: an inter-university collaboration to

advance anatomy education. Anat. Sci. Educ. 2014;7: 501-502.
13. Abou Hashem Y, Dayal M, Savanah S, Štrkalj G. Novel use of 3D bone models in the anatomical sciences education of millennial students: A description of the process and an assessment of the printing accuracy. In: Keator C, editor. The digital era of modern education: Novel teaching strategies and learning approaches designed for millennial students. New York: Nova Science Publishers (in print).
14. McMenamin PG, Quayle MR, McHenry CR, Adams JW. The production of anatomical teaching resources using three-dimensional (3D) printing technology. Anat. Sci. Educ. 2014;7: 479–486.
15. Thomas DB, Hiscox JD, Dixon BJ, Potgieter J. 3D scanning and printing skeletal tissues for anatomy education. J. Anat. 2016;229: 473-481.
16. Cornwall J. The ethics of 3D printing copies of bodies donated for medical education and research: What is there to worry about? Australas. Med. J. 2016;9: 8–11.
17. Alexander M, Marten M, Stewart E, Serafin S, Štrkalj. G. Attitudes of Australian chiropractic students toward whole body donation: A cross-sectional study. Anat. Sci. Educ. 2014;7: 117-123.
18. Abou Hashem Y, Dayal M, Serafin S, Štrkalj G. Students' attitudes toward body image donation for 3D printing. Clin. Anat. 2017;30: 1005–1006.
19. Štrkalj G, Serafin S, Štrkalj M. Using anatomy education to develop the research skills of chiropractic students: a brief report, In: A.P. Giardino, E.R. Giardino (eds.), Medical Education: Global Perspectives, Challenges and Future Directions. New York: Nova Science Publishers, 2013, pp.179-184.
20. Štrkalj G, McGown A, Štrkalj M. Teaching the teachers: A program to educate tutors in anatomy. Australas. Med. J. 2016;9: 253-254.

6/17/2019