3D printing: a valuable resource in human anatomy education

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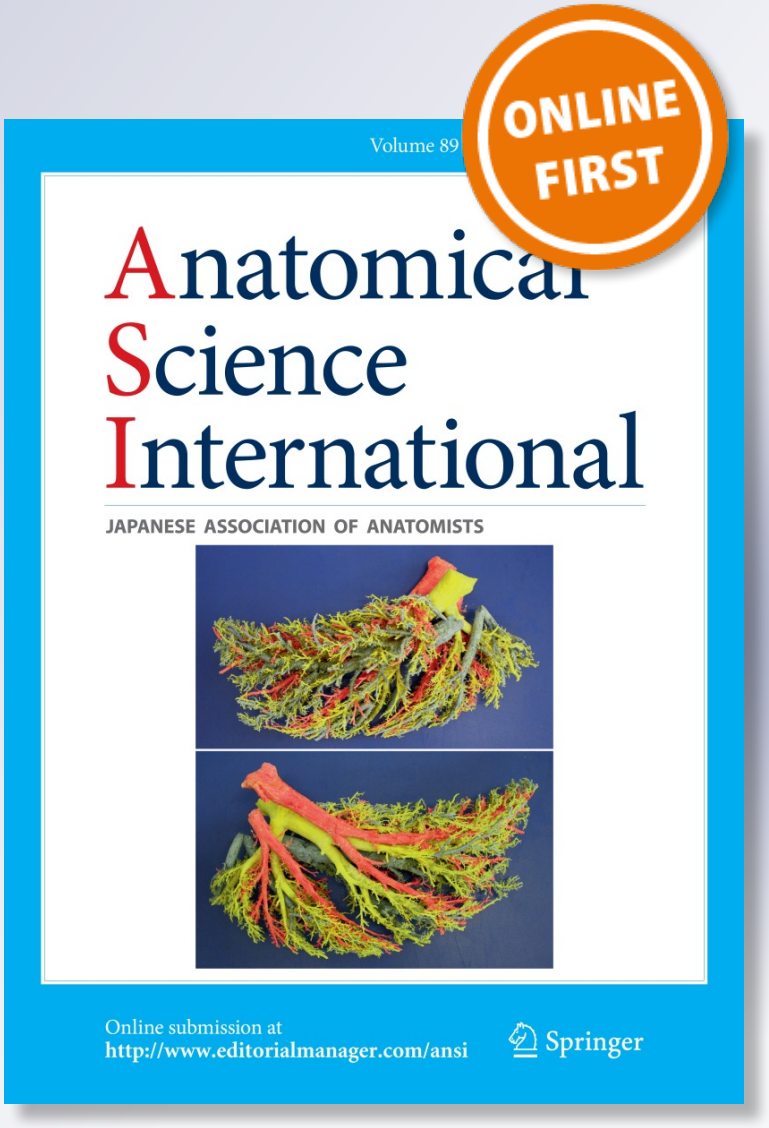

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LETTER TO THE EDITOR

3D printing: a valuable resource in human anatomy education

Mauro Vaccarezza · Veronica Papa

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Anatomy is essential to the health and medical professions: by learning anatomy, medical students learn about the structure of the human body, providing them with the basic tools needed for understanding pathology and clinical problems.

In the past century, dissection and lectures formed the basis of anatomy education worldwide. More recently, traditional anatomy education based on topographical structural anatomy taught in lectures and in gross dissection classes, has been replaced by a multiple range of study modules, including problem-based learning, plastic models and/or computer-assisted learning and curricula integration (Louw et al. 2009).

The anatomy field is strongly confident that donated bodies can still benefit new medical students significantly, and that dissection and pro-section procedures cannot be underestimated in a modern medical curriculum (Louw et al. 2009). Nevertheless, dissection and light microscopy are not problem-free. Storing human bodies is expensive, and other issues such as preservation and reduced suitability for dissection due to illness, age or obesity could be a problem; moreover, careful dissection is time-consuming and microscopy equipment can be expensive. Aside from biological and methodological matters, dissection and pro-section have also issues concerning ethical convictions and legal restrictions or simply logistical problems due to lack of space, funds, recruitment, or proper furniture and equipment.

Considerable variations in the legal and ethical frameworks concerning body bequests for anatomical examination exist worldwide based on cultural and religious variations as well as different legal and constitutional backgrounds. For instance, there are different views concerning the "ownership" of cadavers or the acceptability of using unclaimed bodies that have not given informed consent (McHanwell et al. 2008).

In addition to known methods such as plastination and Thiel method embalming, a new three-dimensional printing system (3D printing) has been developed recently—an innovative approach that could become a valuable resource in anatomy education.

3D printing (also known as additive manufacturing or rapid prototyping) has existed since the late 1980s but has seen rapid advancements more recently because of decreased cost, computer engineering, and expanding applications. Rapid prototyping involves creating a physical 3D model from a computerised mould. The technology has been used in industrial processes to create forerunners of intended final products; models can be also analysed and modified before production is planned (Gibson et al. 2010).

Basically, the principle of rapid prototyping is to use 3D computer models for the reconstruction of a 3D physical model by the addition of material layers (Gibson et al. 2010). With additive fabrication, the machine reads in data from a CAD drawing and lays down successive layers of liquid, powder, or other sheet material, and in this way builds up the model from a series of cross sections. These

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layers, which correspond to the virtual cross section from the CAD model joined together, create the final shape (Gibson et al. 2010).

Currently, the use of 3D printing in medicine can be categorised into three applications: creating models for surgical planning, practice, and teaching; creating implantable prosthetics; and biological tissue engineering (Gibson et al. 2010; Rengier et al. 2010).

Medical imaging has evolved dramatically in the past few decades; nevertheless medical staff are limited by the use of flat screens for the visualization of 3D images. 3D printing can, indeed, overcome these limitations by producing graspable 3D objects. In fact, the intricate, sometimes obscure, structural relationships between cerebral structures, vessels, cranial nerves, and skull base architecture can be difficult to fully comprehend based only on radiographic two-dimensional images; for this reason, it would be very useful for practice and teaching purposes to create anatomically tailored models using 3D printing technology to appreciate fully the anatomic relationships between lesions and the complicated surrounding structures.

Medical applications of 3D printing include tissue engineering for transplantation, clinical applications or both. Probably the most advanced and complicated use of 3D printing technology is to engineer inert scaffolds for biological ingrowths in vivo for transplantation (Rengier et al. 2010).

Recently, a group at Monash University (Melbourne, Australia) headed by Prof. Paul McMenamin put together CT scans, 3D printing and colour software to create a hyper-real facsimile of a human body part (McMenamin et al. 2014). The innovation of the Monash University group was to add to the model even the intricate networks of skin, bone, tissue, blood vessels, tendon and muscle (McMenamin et al. 2014).

Using this kind of model, not only for surgical planning and training but mostly for anatomy teaching purposes, could put a brake on the demand for human body parts and overcome some of the ethical and legal issues governing the use of cadavers.

As already mentioned, the 3D body part is in fact now relatively cheap to create and easy to replicate: it could be a real and valuable source of specimens that could be of paramount importance particularly in countries where dealing with human bodies is frowned upon (such as Muslim countries) and in countries where gross anatomy facilities are lacking and body donations problematic. 3D printing in such cases would provide medical schools a near-identical alternative to the real thing. Furthermore, not only can virtually n-copies be derived from pro-sected specimens, but the specimens obtained can be tailored to highlight different aspects (nerves, vascular network, specific features) of the 3D printed body part.

The ongoing optimisation of 3D printing manufacturing and careful evaluation of pricing in comparison to more traditional methods (as soundly highlighted by McMenamin et al. 2014) will be pivotal to determine the use and the success of this new tool for anatomy education that can substitute proficiently parts of human body as well as prosected specimens.

Conflict of interest None.

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