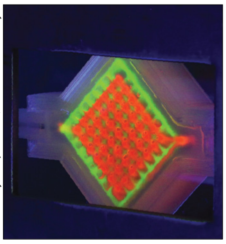
The Lancet Technology: 3D printing for instruments, models, and organs?

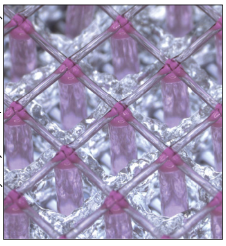
Wyss Institute, Harvard University

Jennifer Lewis



D B Kolesky and J A Lewis, Harvard University

3D vascularised tissues on a perfusable chip



D B Kolesky and J A Lewis, Harvard University

3D network of vasculature (pink) and stem cell-laden ink (clear)

3D printing, or additive manufacturing, has now reached the consumer market. This process creates three-dimensional objects under computer control using successive layers of material. First described in the 1980s, this technology has established commercial and research applications using materials such as metal, plastic, or ceramic. And now the availability of 3D printers, which create small objects by extruding thermoplastic filaments, has prompted renewed interest among researchers.

It is the potential of 3D printing to facilitate just–in-time, specific or tailored objects, manufactured on a small scale, but cheaply and without the need for supply chains, that has got David Armstrong, Professor of Surgery and Director of the Southern Arizona Limb Salvage Alliance (SALSA) at University of Arizona, interested. "I'm evangelical about technology", he says, "but I'm always asking myself 'how can we leverage it to help our people?' If it doesn't work I move on". His team bought a consumer grade fused deposition manufacturing printer, for around US$2000, and printed Army-Navy retractors with polylactic acid, one of the most basic and readily available filaments. The material cost for each retractor was 46 cents, and when printed under clean conditions, the team found, in a research setting, that the instruments would be sterile enough and strong enough for use in an operating theatre. "It seems like there is a possibility there for low-resource settings, or inaccessible areas", he says.

David G Armstrong

3D printed Army-Navy retractors

Armstrong's team also regularly uses the printer for making 3D models for surgical planning before complex procedures. Currently surgeons might examine a 3D rendering of a CT scan of complicated anatomy on a screen, but with 3D printing they have the ability to examine and touch the region of interest before a complex procedure.

3D manufacturing has also allowed surgeons to design and manufacture personalised, anatomically matched implants for use in surgery, particularly in maxillofacial surgery. The ability to produce these implants with consumer grade printers and the rapidly changing nature of the field emphasise both the importance of clear regulation and appropriate evaluation. The US Food and Drug Administration has already cleared some 3D printed devices and issued more generalised draft guidance in May, 2016, but the responsibility for appropriate long-term clinical evaluation rests with the individual surgeons and their institutions.

Jennifer Lewis, Professor of Biologically Inspired Engineering at the Harvard John A Paulson School of Engineering and Applied Sciences, is working at the other extreme of 3D printing using customised multimaterial bioprinters in work towards 3D printing of vascularised tissues and, ultimately, organs. "There is a huge clinical need here. There are about 120 000 people on the organ donation waiting list in the US and 100 000 of those are waiting for kidneys", explains Lewis. Based on a similar principle to commercially available printers, Lewis's printer extrudes cell laden "bio inks" to build up vascularised tissues layer by layer to thicknesses of 1 cm or more. The unique thing about the printed tissue generated in Lewis's lab is the ability to embed tubular channels, which serve as a vascular architecture, throughout the 3D human tissue. "We use a fugitive ink to pattern these cylindrical channels which are co-located near cells of interest…when we then wash this ink away the channels run through the tissue. We can line those channels with endothelial or epithelial or cells that mimic vasculature or kidney proximal tubules", Lewis explains.

There is also the possibility in the future that printed organs could be used extracorporeally as an adjunct or more physiological alternative to dialysis. "Even though we might not reach the stage of a full organ transplant in my lifetime, there is still the possibility of substantial clinical benefit", says Lewis, and there is already interest in 3D printed tissue for "organs on a chip". But as Lewis explains, "we know that cells behave differently in three dimensions—cells in a petri dish, or two-dimensional 'organs on a chip' devices have some limitations". She adds that "our 3D printed tissues could be used for research purposes, particularly drug screening and disease modelling".

The diversity of potential 3D printing applications in medicine and other fields is exciting. 3D printing models are available to download, can be created by computer-assisted design, using a 3D scanner, or a digital camera and online software. "It's like the Napster of things", say Armstrong. "If the knob on your toaster breaks—you could just go online, get the file and print another one." Some of the printed products can then be shredded and the filaments reused. Could this technology allow a move away from mass-produced production line manufacturing that relies on extensive distribution networks? Both Armstrong and Lewis are exploring the options and searching for a way to make this technology work for patients and doctors.

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