

Development of Open Source 3D Bioprinters For Low-Cost and High-Fidelity Biofabrication

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Statement of Purpose: 3D printing has revolutionized the process of design and manufacturing in fields ranging from consumer goods to aerospace to healthcare. A significant factor contributing to the widespread adoption has been the low cost of 3D printing made possible by dedicated open-source and Maker communities. However, this open-source movement has not yet spread to 3D bioprinting, which focuses on the printing of soft, biologically compatible materials. Commercial 3D bioprinters cost from tens to hundreds of thousands of dollars, limiting access to well-funded labs and core facilities. Here we report development of an open-source and low cost 3d bioprinting platform designed for precision deposition of biomaterials using a syringe extruder. To do this we modified several commercially available desktop thermoplastic 3D printers into 3D bioprinters that have performance on par with 3D bioprinters costing orders-of-magnitude more.

Methods: Commercial desktop 3D printers that use thermoplastic filament (e.g. LulzBot Mini, FlashForge Creator Pro, PrintrBot Simple Metal) were purchased for modification. The hotend and associated sensors, heaters, and fans were removed and the extruder carriage was modified to mount our open-source 3D printed syringe pump, called the Replistruder 3 (Fig. 1a). The Replistruder is a positive-displacement direct drive syringe pump. Depending on the printer being modified, the motion control board was either kept stock, or replaced with a more sophisticated 3D printing board (e.g. Duet Wifi, Smoothieboard) to enable multi-material printing. In either case, the firmware was modified to enable 3D bioprinting with the Replistruder. Hamilton gastight syringes were then loaded with bioinks, inserted into the syringe pump, and mounted on the modified extruder carriage. 3D CAD files were processed in open-source slicing programs such as Slic3r to generate the G-code used for printing.

Results: We modified a range of 3D printers and converted these into 3D bioprinters for a cost of \$500-\$2000, depending on the specific printer and number of extruders (Fig. 1b) (1). These printers are compatible with widely used bioinks (e.g. alginate, methacrylated gelatin, collagen, Matrigel), as well as numerous printing methodologies, and multi-material printing (Fig. 1c). These printers can also be utilized for sterile printing if placed in a biohood (Fig. 1d). The Replistruder 3 on the 3D bioprinters is particularly optimized for the Freeform Reversible Embedding of Suspended Hydrogels (FRESH) 3D bioprinting technique developed by our lab (2). With FRESH we can print geometrically complex tissue scaffolds using alginate, collagen and other materials based on MRI imaging data, such as coronary vasculature and models of the human brain (Fig. 1e,f).

Conclusions: We have demonstrated that modifications of inexpensive commercial and open-source thermoplastic 3D printers can produce 3D bioprinters with capabilities rivalling those of systems costing significantly more. We have publicly released our open-source parts, created conversion guides to assist in carrying out these modifications, and have begun to organize workshops to disseminate bioprinting to those that need more hands-on instruction. By lowering the barrier to entry, while retaining or improving printing capabilities, we believe that these open-source bioprinters will spread bioprinting to new fields and serve as a hardware platform for biomaterials innovation.

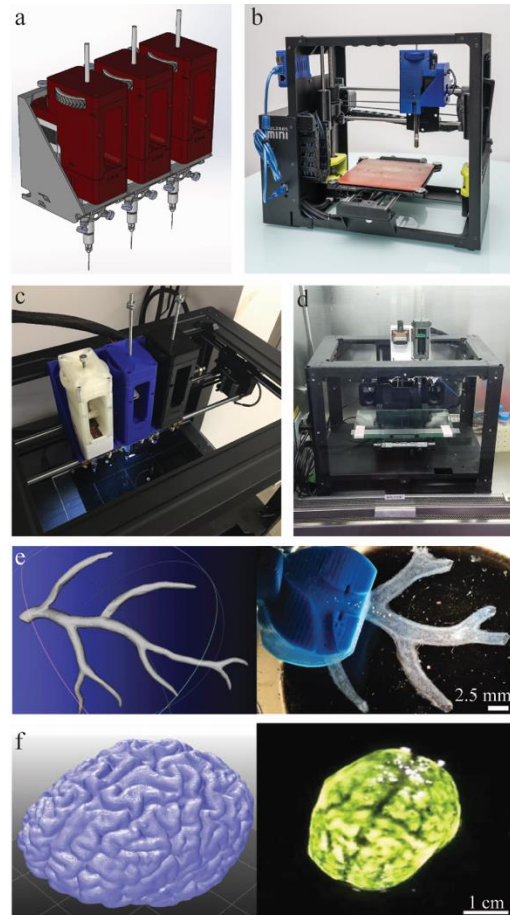


Figure 1: (a) Triple extruder utilizing our Replistruder syringe pump (b) A Lulzbot Mini modified with a single extruder. (c) A triple extruder setup on a modified FlashForge Creator Pro (d) Sterile printing inside a biohood (e) A model of the right coronary artery (left) and an alginate print being perfused (right) (f) Model of a brain from MRI (left) and the printed alginate model (right)

References:

1. Pusch et al., HardwareX (2018), pp 49-61
2. Hinton et al., Sci Adv. (2015), e1500758