3D printing of MRI compatible components: Why every MRI research group should have a low-budget 3D printer

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Target Audience: Researchers interested in custom-made MRI appliances and 3D printing technology.

Purpose: Recently a variety of low-budget 3D printers became available[1,2]. We evaluated the capabilities of a low budget 3D printer and in particular its ability to create a complex multipart MRI compatible head fixation device for mice. The head fixation is custom designed for integration with a dedicated animal coil and a clinical 3 T MRI system.

Material and Methods: An Ultimaker 3D printer (Ultimaking Ltd., 4191PL Geldermalsen, Netherlands) including the optional UltiController kit (Fig. 1) was used. The available build volume is limited to 210 mm x 210 mm x 205 mm. Although the positioning of the print head can theoretically achieve a resolution of 0.0125 mm, the actually printable structures are limited by the nozzle diameter of 0.4 mm. The layer thickness was set to 0.1 mm for fine details and good print quality. All parts were fabricated from the bio compatible material Polylactic Acid (PLA). The individual parts of the mouse fixation were custom fit for integration with a 38mm diameter Litz coil (Doty Scientific Inc., Columbia, SC, USA) at a clinical 3T scanner (TIM Trio, Siemens Healthcare, Erlangen, Germany). The mouse bed and head fixation (Fig. 2) facilitates head fixation with a bite bar and a hinged head clamp mechanism, anesthetic gas supply and biomonitoring sensors through 3D printed hollow channels. The individual parts were designed using the CAD software Solidworks 2012. The preprocessing for the 3D printer was performed with the slicing program Cura which is developed by Ultimaking Ltd and provided as open source software. All cylindrical and rounded parts were printed in an upright position to reduce the required support structures for overhanging object structures and to keep the footprint of the printed objects small, which reduced warping problems. After printing the support structures were mechanically removed.

Results: All parts were successfully printed within 20 h and assembled (Fig. 3), creating a mouse fixation with a total weight of 135 g, corresponding to material costs of approximately 5 $US. The printed parts were fully functional with well defined details and low tolerances (<0.4mm). MR images of the mouse head clearly showed reduced motion artifacts, ghosting and signal loss when using the fixation (Fig 4).

Discussion and Conclusions: We have demonstrated that a low budget 3D printer can be used to quickly progress from a concept to a fully functional device at very low production cost[3,4]. While 3D printing technology does impose some restrictions on model geometry, e.g. size and overhanging structures, additive printing technology can nonetheless create objects with complex internal structures which are impossible to create using conventional lathe technology[1,2]. The material PLA consists of polymerized lactate and possesses a susceptibility similar to biological tissue rendering it ideal for MRI environments as it is both bio and MRI compatible. In its frozen glass like state at room temperature PLA is invisible even at ultra short echo times of 70µs. Other interesting applications of 3D printing in MRI are customized cases and protections for self made coils, customized phantom or sample holders. In conclusion we consider a 3D printer a valuable asset for MRI research groups.

References: [**1**] Upcraft S, Fletcher R. Assembly Automation 2003;23:318–330. [**2**] McMains S. Communications of the ACM 2005;48:50–56. [**3**] Pearce JM. Science 2012;337:1303–1304. [**4**] Zhang C, Anzalone NC, Faria RP, Pearce JM. PLoS One 2013;8:e59840.

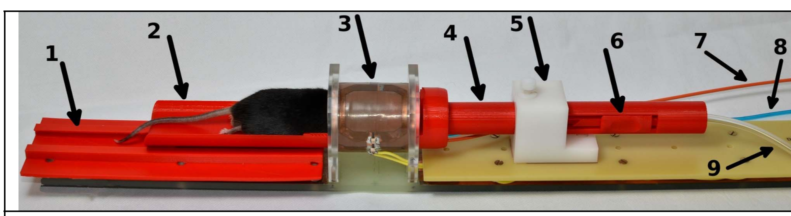
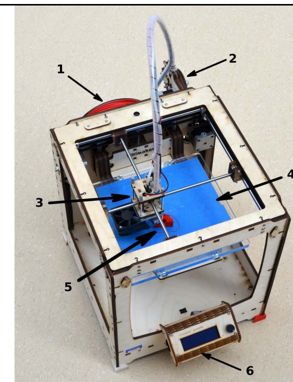


Fig. 3: Complete assembly of the 3D printed mouse fixation (all red parts) mounted on the original coil platform with the added mounting block (white, 5). The main parts are the T-groove platform (1), which supports the tail end of the mouse bed (2). The head fixation mask is positioned inside the Doty coil (3). The cylinder (4) is screw locked by the white mounting block (5). Inside the cylinder (4) the bite bar can be moved using the finger grips (6) and the anesthetic gas is supplied through the bite bar. All three leads, the fiber optic temperature sensor (7), the pressure pad tube (8) and the gas supply tube (9) are connected from the front of the coil assembly, which eases handling.

Fig. 1: Ultimaker 3D printer with Control unit (6): The PLA supply (1) is pushed by a stepper motor (2) towards the heated print head (3) where the PLA is molten and extruded onto the building table (4) similar to a *x*-*y*-plotter. The print object (5) grows layer by layer while the build table moves downward (*z*-axis).



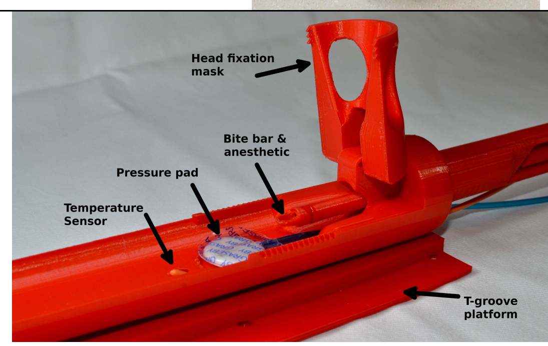


Fig. 2: The mouse head fixation with opened fixation mask, the bite bar, which also supplies the anesthetic gas, the pressure pad for respiratory monitoring and the temperature sensor. The mouse bed can be slid along the t-groove platform, which keeps the fixation device stable during animal manipulation.

Fig 4: T2-weighted MRI images with (a) and without (b) the head fixation. The fixation strongly reduces motion artifacts and signal loss, in particularly visible in the soft tissue areas.