Characterization of B0 and B1 maps in 3D printer materials at 9.4T

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Introduction: Fabrication of custom designed mechanical parts play an integral role in conducting MR research. Utility of 3D printers are especially suitable for this purpose and have been recognized because they facilitate rapid fabrication, duplication, and distribution. Recently, consumer grade 3D printers have been adopted for fabricating a cost effective MRI compatible small animal bed [1]. While utility and design of fabricated objects are reported, studies have yet to investigate impact of the building materials onto static magnetic field (B0) and RF field (B1). The aim of this study was to characterize the interaction between the B0 and B1 fields in the presence of commonly used building materials (PLA, ABS and photo polymer resin) in 3D printers.

Method: A phantom comprising 0.9% NaCl solution was prepared in a cylindrical glass tube (15mm in diameter and 47mm in length) and maintained at 20°C. An octagonal shaped sleeve was designed by FreeCAD software and fabricated using MendelMax or Formlab consumer grade 3D printers as shown in Figure. 1. Three building materials were tested in this study: polylactic acid (PLA), acrylonitrile butadiene styrene (ABS) and photo-polymer resin. In both PLA and ABS plastics, the objects were printed in different air-plastic fill densities (30%, 60%, 90%). Imaging was performed using a 9.4T Bruker magnet, equipped with a volume RF transmit/receive coil (ID=64mm) controlled by PV 5 software. Following the first order shimming, a 3D dual gradient echo sequence (TR=20ms, TE1=1.46ms, TE2=5.74ms, 0.8x0.8x0.8mm) was acquired and a B0 map was calculated using the MAPSHIM algorithm. B1 maps were calculated by using the dual flip angle method [2] using 2D RARE sequence (TR=10000ms, TE=40ms, Flip angle=80° and 160°, 0.2x0.2x0.9mm). A set of B0 and B1 maps were calculated for the 7 conditions (no-sleeve, resin, fill densities of 30, 60, and 90% in both ABS and PLA plastics) and repeated twice to evaluate test-retest reliability for each condition. B0 and B1 difference maps were calculated, expressed as $\Delta B0=B0_{sleeve}-B0_{no\text{-}sleeve}$ and $\Delta B1=|B1_{sleeve}-B1_{no\text{-}sleeve}|/80°*100\%$, in quantifying any B0 or B1 alteration caused by the fabricated materials.

Result: As shown in Figure 1, difference maps between absence and presence of the sleeve resulted in substantial B0 differences near the ring of the sleeve, and it was defined as a region of interest (ROI) for subsequent analyses. Test-retest of B0 maps yielded ΔB0 ranging 13~42Hz within the ROI. ΔB0 between "sleeve vs no sleeve" yielded ~160 Hz irrespective of the fill densities and the materials as shown in Figure 2. Test-retest of B1 yielded ΔB1 around 1%, comparable to "sleeve vs no sleeve" in all materials irrespective of the fill densities as shown in Figure 3.

Conclusion: In this study, we report building materials in the 3D printers result in measurable B0 changes in 9.4T field strength. The effect of B0 changes were not spatially uniform and may depend on mass, shape, and size of the fabricated object, potentially aggravating susceptibility related imaging artifacts [3]. In B1 maps, we report no measurable effects were observed in the presence of the materials. B1 differences between the absent and presence of the fabricated objects were within fluctuation of the test-retest reliability.

Figure. 1

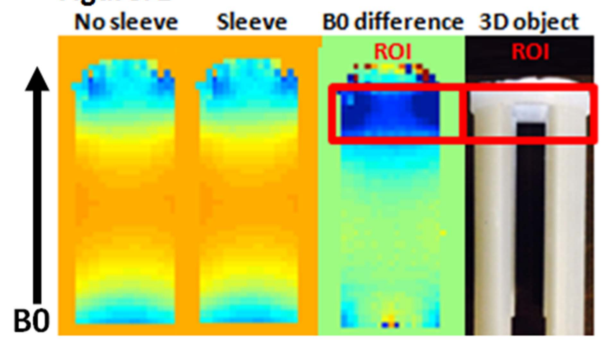


Figure. 2 B0 difference

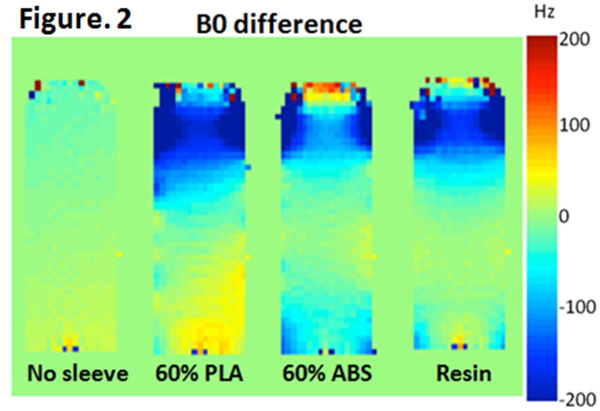
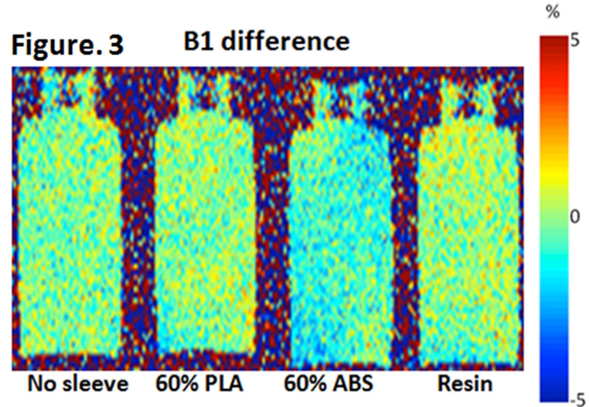


Figure. 3 B1 difference



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