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Bio-Inks for 3D Inkjet Printing of Vasculature: Feature Resolution and Interfacial Energy

Inkjet printing is a versatile tool used in additive manufacturing/3D printing with the benefit of multi-material deposition of picolitre volumes of material. A number of previous studies have demonstrated the utility of inkjet printing in producing vascularized structures and depositing cells for applications in tissue engineering and regenerative medicine. Despite the small droplet size delivered by inkjet printing (a 1 pL drop has a diameter of approximately 12.5 µm), state-of-the-art bioprinted structures have minimum features in the range 100 – 200 µm and have shown little improvement in resolution over the last 10 years. In order to print vascularised structures to allow transport of oxygen and nutrients to prototissues in culture, this current resolution may not be adequate.

In order to print vascular structures a sacrificial temporary support material is used to define the vasculature around which a hydrogel matrix is deposited. The sacrificial material is removed and replaced with culture media or a similar fluid once the construct is built. The width of a printed line is the resolution limiting lateral dimension for 3D printing and hence the minimum dimension of the vascular channels. Currently 3D printed vascular structures, using both inkjet and extruded filament methods, have been fabricated from gelatin methacrylate (GelMA) using a poloxamer fugitive hydrogel (Pluronic F127) for the vasculature. The minimum feature size is ≈ 200 µm in the x-y plane, the limiting factor is the high degree of wettability of the inks on the gelled deposit from their low contact angle; low contact angles lead to poor lateral resolution. Here we present results using a new approach and material formulation for the vascular material using formulated and modified gelatine based bioinks for both the vasculature and the hydrogel matrix. This allows better control of interfacial energies and leads to improved printed feature resolution. The approach also simplifies the design of the printer by allowing similar temperature control for both inks, unlike the case with poloxamer/GelMA inks where the two printed components must be delivered at different temperatures.