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Microfluidic-based 3D bioprinting for fabrication of helical fibres

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INTRODUCTION: 3D extrusion-based bioprinting has emerged as a promising technology for development of advanced and viable organs and tissues and functional 3D in vitro disease models [1,2]. However, these developments have failed to recapitulate the heterogeneity and complexity (e.g. helical structures) of organs and tissues. Recent studies [1,2] have demonstrated the potential use of microfluidic-based 3D printing by allowing more control and precision over the organisation of biomolecules, cells and material thus, enabling fabrication of complex 3D constructs. Herein, we developed an agile manufacturing pipeline based on COntinously Varied Extrusion (CONVEX) [3] design approach in extrusion-based printing to develop integrated 3D-printed microfluidic chip nozzles, based on microfluidic mixers and hydrodynamic flow focusing components with the potential to fabricate complex helical fibres.
METHODS: FullControl GCode designer software [4] was used to extrude a single layer of acrylonitrile butadiene styrene (ABS) with zigzag passive mixer component using an Ender 3 3D printer. The ABS channels were cast into polydimethylsiloxane (PDMS) before flushing with acetone. To achieve co-axial hydrodynamic flow focusing of calcium chloride-Pluronic solution by 2wt% sodium alginate solutions, the calcium chloride channel had a smaller diameter than sodium alginate channels.
RESULTS: Complex passive mixer region zigzag region has enabled rapid on-fly mixing of two fluids, while achieving flow-focusing capabilities through cross junction design, resulting in formation of helical fibres. 3D-Helical fibres are among the most interesting and innovative structures in nature, representing an emerging group of materials with distinct unique spiral geometry and multiple excellent functionalities. However, their fabrication at micro-scale level remains a challenge. This work presents an innovative and highly adoptable 3D-printed fluidic chip system, with the functions of consecutive spiralling for scalable generation of helical fibres. The generation of helical structures can be precisely optimised by varying the flow rates; therefore the length, diameter and pitch of the helical structures are highly controllable.
DISCUSSION & CONCLUSIONS: An agile manufacturing pipeline has been developed to fabricate novel microfluidic chip nozzles suitable for 3D bioprinting of complex tissues and organs. Microfluidic chip nozzles allowed dynamic and precise control of the diameter of core/shell hydrogels. Future work will integrate the microfluidic chip nozzle on a 3D printer to fabricate complex 3D structures containing cells.
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