FABRICATION OF MULTI-LAYERED BIOMATERIALS FOR VASCULAR APPLICATIONS THROUGH SUB-ZERO BIOPRINTING

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Introduction

Cardiovascular diseases are a leading cause of mortality globally, causing significant financial burden [1]. Coronary artery bypass surgery is the current standard treatment, but it can cause complications through the mismatch between the implant and host tissue [2]. The potential of the additive manufacturing (AM) of biomaterials have yet to be fully explored as potential solutions [3]. To date, the AM of PVA (polyvinyl alcohol, a versatile biomaterial that mimics arterial tissue [4]) and/or the resulting mechanical properties, have been limited by the manufacturing technique. In this study, the application of sub-zero, temperature-controlled, bioprinting enables fabrication of multi-layered samples. The effectiveness of this technique is evaluated against the tensile strength relative to the number of layers.

Methods

The design of 50×50×1.5 mm^3 samples geometry was created using Fusion 360 (Autodesk, California, United States). The designed geometry was converted into G-Code through the slicing software REGEMAT 3D designer (REGEMAT 3D S.L., Granada, Spain), using an alternating 0-90 degree infill. A solution of 11% w/w PVA (146–186 kDa) and hydrolysis of 99 + % (Sigma-Aldrich, Missouri, USA), was dissolved in deionised water by autoclaving for 1 h at 121°C, then mechanically stirred at 50°C for 1 h and further continuous stirring for 1 h until the solution reached room temperature (RT) (22.5 ± 1°C). A Regemat BIO V1 bioprinter (REGEMAT 3D S.L., Granada, Spain) was used to additively manufacture the samples. The samples were printed with a 0.58 mm nozzle in a multi-layer configuration, with each layer having a thickness of 0.25 mm (Figure 1). The printing temperature was maintained at -8°C throughout the printing process. After AM, all samples underwent 24 h freeze–thaw cycles (FTC) at −20°C and RT respectively. The samples were kept in deionised water for 4 days and then mechanically tested using a uniaxial tensile ramp test and a load cell of 2.5 N. The samples were clamped at both ends, preloaded and a displacement of 9.6 mm (+19.2% of initial sample length) was applied at a constant rate of 0.25 mm/sec. The load and displacement were recorded throughout the test, and the resulting load-displacement plot was used to evaluate the mechanical properties of the samples.

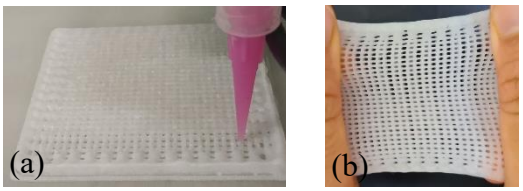

Figure 1(a,b): 6-layered sub-zero bioprinted sample

Results

The preliminary, raw load and displacement results are shown in Figure 2. The samples represent 6 alternating (parallel / perpendicular) layers after 2FTC and 3FTC. An increase in the tensile strength of the samples was observed with increasing layers and FTC.

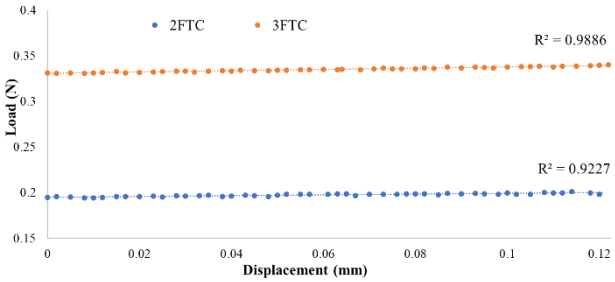

Figure 2: Preliminary, raw load vs displacement results

Discussion

This study has presented a sub-zero bioprinting approach which shows potential towards fabrication of functional cardiovascular biomaterials. The method presented in this research, enables precise layering and homogeneity of PVA biomaterials, but results can vary depending on the number of layers, FTC, and printing parameters. This research provides a foundation for further studies to optimise conditions and investigate the materials potential for cardiovascular tissue engineering applications. The flexibility of AM could enable the fabrication of materials with variable mechanical properties, often described as functional graded materials via AM.

References

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