Characterization of mechanical properties and microstructure of hydrogel scaffolds by X-ray propagation-based imaging

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Introduction

Characterization of the mechanical properties and internal microstructure of scaffold, once implanted, is imperative in tissue engineering and medicine regeneration. Notably, this has been challenging to date as various conventional characterization methods by, for example, mechanical testing (for mechanical properties) and microscope (for internal microstructure) are destructive as they require removing scaffolds from the implantation site and processing samples for characterization.

Synchrotron radiation X-ray propagation-based computed tomography (SR-PBI-CT) is feasible and promising for non-destructive monitoring of hydrogel scaffolds [1-2]. With the high brightness and high coherence of synchrotron radiation source, SR-PBI imaging is able to visualize and distinguish low-density soft tissues and hydrogels with high spatial resolution and scan speed [1], while the feature of large imaging depth with X-ray CT ensures the reconstruction of the three-dimensional (3D) scaffold. As inspired, this study aimed to perform a study on the characterization of mechanical properties and microstructure of hydrogel scaffolds by the SR-PBI-CT imaging.

Materials and methods

The biomaterial solutions were prepared from 3% w/v alginate + 1% w/v gelatin and then printed by using the needle with a diameter of 200µm, to form scaffolds with a dimension of $10\times10\times5mm^3$. The printed scaffolds were crosslinked in 100 mM/L calcium chloride solution for 48 hours. Some of the scaffolds were degraded in a 37°C media of phosphate buffered saline over 3 days, for the subsequent examination, along with those without degradation.

The scaffolds both with and without degradation were subject to compressive testing on biodynamic system from BOSE, where the compression speed was set at 0.1 mm/s to reach the strain of 10%, 20%, 30%, 40%, and50%, respectively. Once reached, the strain was held for 5 minutes for measuring the force and thus the stress in scaffolds, yielding the stress–strain curves. Then, the SR-PBI-CT imaging were performed at the BMIT-ID beamline, Canadian Light Source (CLS), Canada. The scaffolds were loaded with the strains as same as compressive testing and at each strain, the scaffold was imagined and scanned with a pixel size of 13 µm for analyse.

Results and discussion

Fig. 1(a) shows the representative of stress-strain curve, along with the stresses and Young's moduli evaluated verse the strain; while Fig. 1(b) shows the scaffolds microstructures featured by strand cross-section area, pore size, and hydrogel volume during compression. Our results have illustrated that the mechanical properties and microstructures of scaffolds, either being degraded or not, can be examined and characterized by the SR-PBI-CT imaging, in a non-destructive manner.

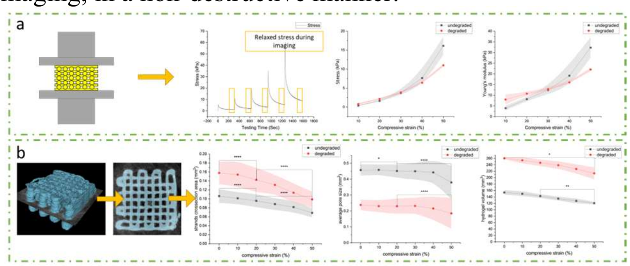

Fig. 1 *Result of both mechanical properties and internal microstructure of the examined scaffolds. Stress-strain curve and elastic moduli (a). Strand cross-section area, pore size, and hydrogel volume change during compression (b).*

Conclusion

The study reveals the potential of applying SR-PBI-CT to visualize and characterize hydrogel scaffolds in terms of their mechanical properties and microstructures in a non-destructive manner. This would represent a significant advance for facilitating longitude studies on the scaffolds once implanted in vivo.

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References

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