ELECTROSPUN SHAPE MEMORY SCAFFOLDS FOR BONE TISSUE ENGINEERING

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INTRODUCTION: Emulsion electrospinning is extensively used to make tissue engineering scaffolds with the capability of delivering bioactive agents such as growth factors [1]. Bone morphogenetic protein-2 (BMP-2) is a potent growth factor for osteogenesis. On the other hand, shape memory polymers (SMPs) have attracted great attention in tissue engineering[2]. An SMP device can be packed into a temporary shape with a much reduced size. After implantation through a narrow path, the device may recover to its larger and permanent shape upon specific stimulus. Another important issue is electrospinning of thick, 3D scaffolds. This study investigated electrospinning of a shape memory polymer, poly(D,L-lactide-co-trimethylene carbonate) P(DLLA-co-TMC), into thermo-responsive scaffolds. An auxiliary process was studied for facilitating the formation of thick scaffolds.

MATERIALS AND METHODS: An established procedure was used for emulsion electrospinning to fabricate rhBMP-2 encapsulated scaffolds [1]. To make w/o emulsions, rhBMP-2 (with BSA as stabilizer) in deionized water were blended with P(DLLA-co-TMC)/chloroform solution and a surfactant. Electrospinning parameters, i.e., applied voltage, working distance, solution feeding rate and electrospinning duration, were set at 10kV, 10cm, 4ml/h and 2h. During electrospinning, the fiber collector was filled with liquid nitrogen and hence ice particles were formed on collector surface, which facilitated formation of thick scaffolds continuously. Afterwards, scaffolds were freeze-dried to remove ice particles and solvent. The scaffolds were examined using SEM and TEM. In vitro release of rhBMP-2 was studied using ELISA kit assay. The shape memory effect was also evaluated.

RESULTS AND DISCUSSION: The new technique could produce thick P(DLLA-co-TMC) scaffolds incorporated with rhBMP-2. Within 2 h, scaffolds with a thickness of 4 mm were made (Fig.1a). This was attributed to the formation of ice particles between layers. SEM examination revealed multi-layered scaffolds structure and some hollow fibers were observed. The top view of scaffolds showed that scaffolds were non-woven (Fig.1b). The pore size in the scaffolds was comparable to that of conventional electrospun scaffolds. TEM results showed fibers had a core-shell structure (Fig.1c). In compression tests, when the force was applied on the cross-section of scaffolds, scaffolds exhibited compressive strength as high as 0.8-1.3MPa (Fig.2a). In vitro release experiments showed that rhBMP-2 had a fast release in the first 24 h, followed by a slow but sustained release to the 45% level by the end of 28-day test period. For shape memory, rhBMP-2/P(DLLA-co-TMC) had a high fixation ratio at room temperature and could recover to its permanent shape from the temporary shape in 1 min at 37oC (Fig.2b). When a higher temperature was applied, the scaffolds would go back to their original shape within a shorter time.

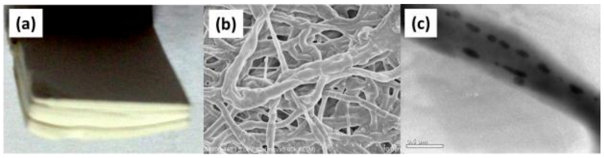

Fig. 1. (a) Macrograph of scaffolds; (b) non-woven fibrous structure of scaffolds; (c) TEM micrograph showing core-shell structure of emulsion electrospun fibers.

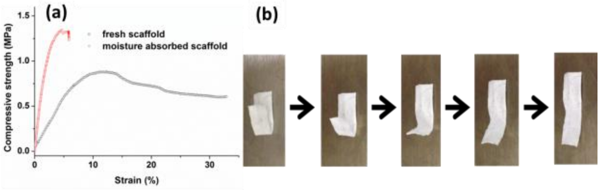

Fig. 2. (a) Compression test curves for scaffolds produced; (b) shape memory of scaffolds at 37 ºC.

CONCLUSION: This study showed that thick, rhBMP-2 incorporated P(DLLA-co-TMC) scaffolds with excellent shape memory ability could be made using emulsion electrospinning with the assistance of ice particles formed on the fiber collector (which was induced by liquid nitrogen inside the fiber collector). The scaffolds possessed good mechanical properties, and controlled rhBMP-2 release could be achieved with the scaffolds.

REFERENCES:

[1] C. Wang, M. Wang, Dual-source dual-power electrospinning and characteristics of multifunctional scaffolds for bone tissue engineering, J Mater Sci Mater Med, 2012, 23:2381-97.

[2] A. Lendlein, et al. Shape-memory polymers as a technology platform for biomedical applications, Expert Review of Medical Devices 7, 357-379, 2010