Supporting information

A bio-inspired high strength three-layer nanofibers vascular graft with structural guided cells growth†

Kai Liu,‡[a] Nü Wang,‡[a] Wenshuo Wang,[b] Lianxin Shi,[b] Hao Li,[c] Fengyun Guo,[a] Lihua Zhang,[a] Liang Kong,[d] Shutao Wang*[b,e] and Yong Zhao*[a]

a. Key Laboratory of Bio-inspired Smart Interfacial Science and Technology of Ministry of Education, School of Chemistry and Environment, Beihang University Beijing 100191, P. R. China

b. Laboratory of Bio-inspired Smart Interface Science, CAS Center for Excellence in Nanoscience, Technical Institute of Physics and Chemistry, Chinese Academy of Sciences, Beijing 100190, P. R. China.

c. State Key Laboratory of Supramolecular Structure and Materials, School of Chemistry, Jilin University, Jilin 130012, P. R. China.

d. Oral Hospital of The Fourth Military Medical University, Xian 710032, P. R. China

e. University of Chinese Academy of Sciences, Beijing 100049, P. R. China.

†. Electronic Supplementary Information (ESI) available: See DOI: 10.1039/x0xx00000x.

‡. These authors contributed equally.

**Email: zhaoyong@buaa.edu.cn*

**Email: stwang@mail.ipc.ac.cn*

Choose the material of each layer of 3LVG.

Each layer of 3LVG provided unique function that inner and outer layer which contacted directly cells should possessed good biocompatibility, but meddle layer should have good mechanical properties for preventing vascular ruptured.

Biocompatible rigid PLA and soft PCL were chosen to fabricate inner and outer layer of vascular graft for their excellent biocompatibility as reported before.[1] But weak of them was low mechanical properties. In order to find optimized mechanical properties of rigid PLA and soft PCL, five mass ratios of PLA/PCL (3:7 w/w, 1:1 w/w, 7:3 w/w, pure PLA and pure PCL) were investigated. Observed under SEM, different mass ratios of PLA/PCL fibers had no obvious difference in morphology. Diameter ranged from 0.58 ± 0.19 μm to 1.34 ± 0.33 μm (Fig. S1). Mechanical properties of different mass ratio films were also measured (Fig. S2) (In the process of chosen material of each layer of 3LVG, we measured mechanical properties of the electrospun films). We found that when the mass ratio of PLA/PCL was 3:7 w/w, max stress of composite film was 3.5 ± 0.4 MPa and max breaking strain reached 164 ± 15% (Fig. S2). Therefore, PLA/PCL (3:7 w/w) was chosen as inner and outer layer materials.[1-3] Although we find a good mass ratio mechanical properties of PLA/PCL (3:7 w/w), mechanical properties of PLA/PCL (3:7 w/w) are still not strong enough as the supporting layer.

On the contrary, PU/PCL is good strength and elastic material, but its biocompatibility is not as good as PLA/PCL (PU/PCL is still a non-toxic material). PU/PCL (3:1 w/w) was chosen for fabrication middle layer of 3LVG under consideration of the mechanical properties.[4-5] Composite electrospun film (PU/PCL) had tensile strength of 45.0 ± 4.6 MPa and breaking strain of 511 ± 87%. It's an ideal candidate material for its good mechanical properties.

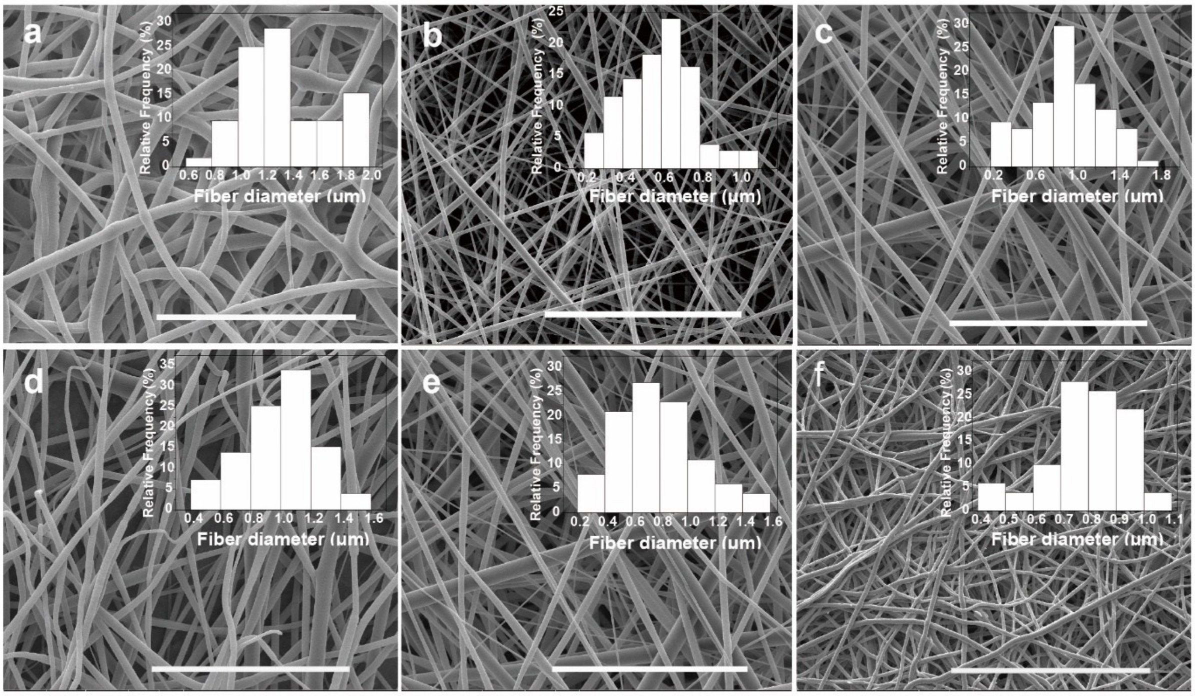

Fig. S1 SEM images of different mass ratio of PLA/PCL and PU/PCL. (a) Pure PCL. (b) Pure PLA. (c) PLA/PCL (3:7 w/w). (d) PLA/PCL (1:1 w/w). (e) PLA/PCL (7:3 w/w). (f) PU/PCL (3:1 w/w). Scale bars = 30 μm.

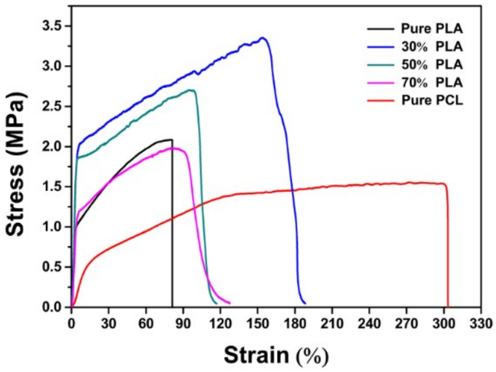

Fig. S2 Mechanical properties of different mass ratio of PLA/PCL film. Representative tensile stress-strain curves of different mass ratio of PLA/PCL. The compositing of these two materials with appropriate mass ratio will overcome their weakness so that it would reach good mechanical properties with high stress and strain.

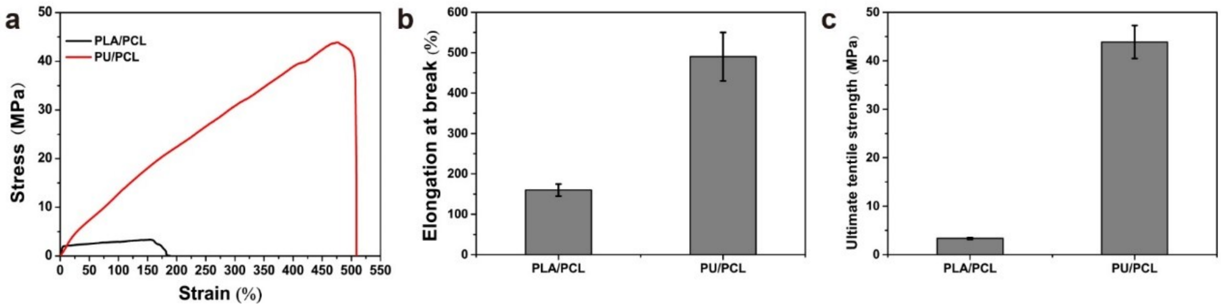

Fig. S3 Mechanical properties of PLA/PCL (3:7 w/w) film and PU/PCL (3:1 w/w) film. (a) Representative tensile stress-strain curves of PLA/PCL (3:7 w/w) and PU/PCL (3:1 w/w). (b) Elongation at break. (c) Ultimate tensile strength.

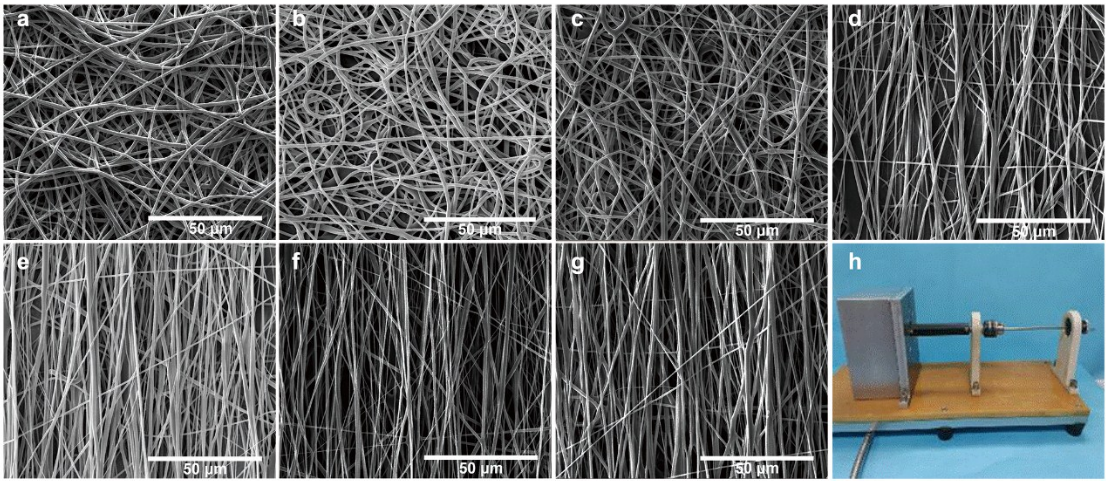

Fig. S4 SEM images of fibers at different received speed. (a) 0 rpm, (b) 400 rpm, (c) 800 rpm, (d) 1200 rpm, (e) 1600 rpm, (f) 2000 rpm. (g) 2400 rpm. (h) The received device.

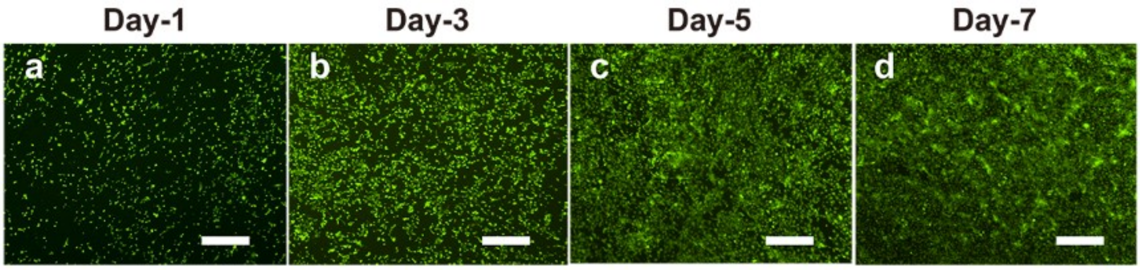

Fig. S5 The proliferation of HUVECs on the surface of vascular grafts. Image (a), (b), (c) and (d) are the proliferation fluorescent staining of HUVECs with cultured days (1, 3, 5 and 7 days) indicating high proliferation of HUVECs. Scale bars = 500 μm.

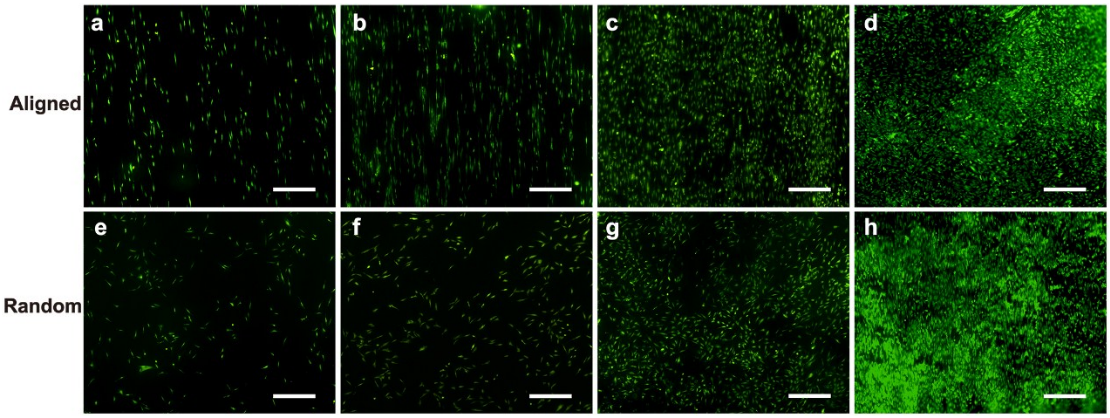

Fig. S6 Fluorescent images of VSMCs which seeded on the two kinds of outer layer of 3LVG. (a) - (d) Images of VSMCs seeded on aligned fibers outer layer of 3LVG. (e) - (h) Images of VSMCs seeded on random fibers outer layer of 3LVG. The cultured time was 1, 3, 5 and 7 days. Scale bars = 500 μm.

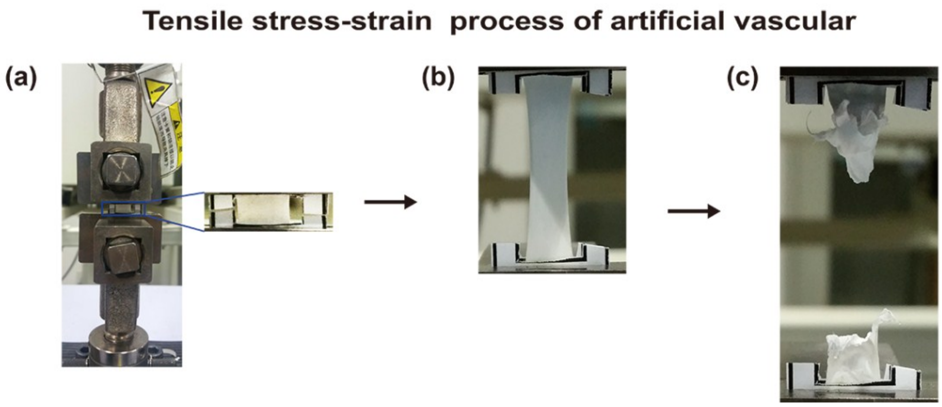

Fig. S7 The digital photos of tensile stress-stain process of artificial vascular. (a) Beginning of tensile test, the vascular graft was fixed by two clamps and pulled off by the test machine. (b) The vascular graft was pulled at large strain level. (c) At the time of completely rupture of vascular graft.

Notes and references

1 T. C. Rothuizen, F. F. R. Damanik, T. Lavrijsen, M. J. T. Visser, J. F. Hamming, R. A. Lalai, J. M. G. J. Duijs, A. J. van Zonneveld, I. E. Hoefer, C. A. van Blitterswijk, T. J. Rabelink, L. Moroni and J. I. Rotmans, *Biomaterials*, 2016, **75**, 82-90.

2 V. M. Merkle, D. Martin, M. Hutchinson, P. L. Tran, A. Behrens, S. Hossainy, J. Sheriff, D. Bluestein, X. Wu and M. J. Slepian, *Acs Appl. Mater. Interfaces*, 2015, **7**, 8302-8312.

3 T. Dvir, B. P. Timko, M. D. Brigham, S. R. Naik, S. S. Karajanagi, O. Levy, H. Jin, K. K. Parker, R. Langer and D. S. Kohane, *Nat Nano*, 2011, **6**, 720-725.

4 M. R. Williamson, R. Black and C. Kielty, *Biomaterials*, 2006, **27**, 3608-3616.

5 F. Guo, N. Wang, L. Wang, L. Hou, L. Ma, J. Liu, Y. Chen, B. Fan and Y. Zhao, *J. Mater. Chem. A*, 2015, **3**, 4782-4787.