Preparation and evaluation of small diameter blood vessels with different woven structures fabricated from biopolymer yarns

[1]Yu Xie, [2]Xiaoyuan Yang [1]Rahim Jindani, [1,2]Martin W. King.
[1]College of Textiles, North Carolina State University, Raleigh, NC27695, [2]Donghua University, Shanghai, China 201620.

Introduction: Coronary arterial diseases (CAD) and peripheral arterial diseases (PAD) are dominant cardio-vascular diseases accounting for 24.2% of the mortality rate in United States. The gold standard materials for by-pass surgery are autologous vessels, such as the saphenous vein or the internal mammary artery, which may not be available due to aging, previous harvesting or the pre-existing arterial disease [1, 2]. Synthetic ePTFE and polyester (PET) have served as successful vascular grafts with diameters greater than 6mm, but they are not suitable for small vascular grafts. Limited patency rates mainly due to poor circumferential compliance and high thrombogenicity have been observed in patients with small caliber synthetic grafts. Thus the goal of this study is to improve the long-term patency rates of small diameter blood vessels by developing structures that use natural biopolymer materials, such as silk fibroin.

Methods: Two different silk yarns (204 denier and 84 denier) with sericin coatings were provided by Soho International Silk Co. Ltds., Jiangsu, China. In addition Goretex® 6mm diameter vascular prostheses were included as clinical controls. Three tubular samples were woven utilizing 1/1 plain weave, 2/2 and 1/3 twill weaves, as shown in Figure 1. The silk vascular prostheses were degummed after weaving by immersing in sodium carbonate buffered solution (0.05 wt %) at pH 10.6 at 90ºC for 90 min. The diameter of the tubes was then evaluated on a mechanical tester (Model: YG-B 026H) following the standard method described in ISO 7198 [2]. The compliance of the samples was measured by an Enduratec dynamic mechanical simulation system (Bose Corporation) [2]. Further testing involved the measurement of circumferential stength, suture retention strength, water permeability and cytocompatibility by culturing porcine iliac endothelial cells and using an MTT viability assay.

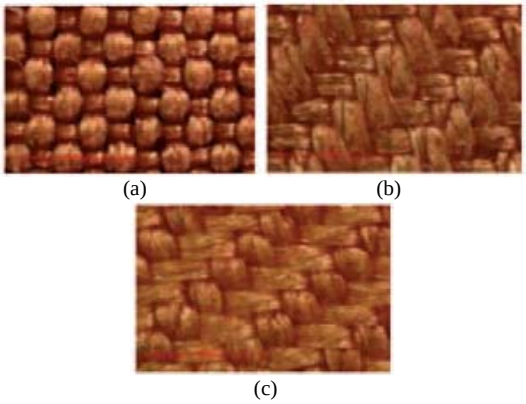

Figure 1 Photographs of woven samples, showing 1/1 plain (a), 2/2 twill (b) and 1/3 twill (c).

Results: From among the many experimental test results, the results of circumferential compliance are shown here in Figure 2. There is no significant difference between the three biopolymer silk-based samples. Sample 31 (1/1 plain), 32(2/2 twill) and 33(1/3 twill) are all more compliant than the ePTFE control, but less compliant than the pig's carotid artery. It would be interesting to observe and compare the results of woven collagen vascular prostheses with these current results in the future.

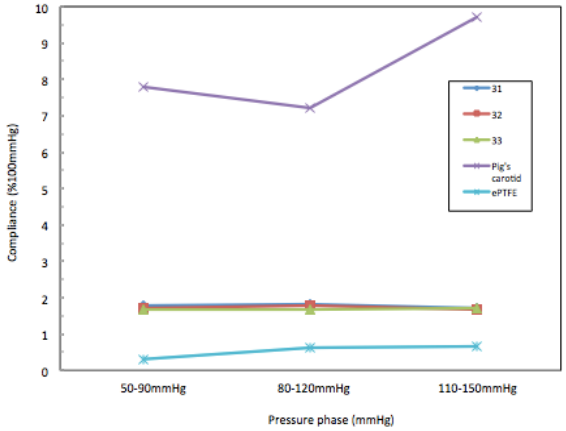

Figure 2. Comparison of compliance of the biopolymer silk samples, ePTFE commercial graft, and a pig's natural carotid artery.

Conclusions: From the observed results one can conclude that the woven silk prostheses have better compliance than the ePTFE commercial arterial prosthesis. The type of woven structure has minimal impact on the compliance, while the highest suture retention strength was obtained with the 2/2 twill weave. Positive cell viability was observed on all 3 silk samples regardless of the woven structure. Further studies will include fabricating collagen-based blood vessels with different woven structures and comparing the mechanical and biological properties with those of silk vascular grafts. Collagen yarns with promising mechanical properties have been developed from tissue-engineered collagen generated in sheet form [3].

References:

[1] Konig, Gerhardt, et al. "Mechanical properties of completely autologous human tissue engineered blood vessels compared to human saphenous vein and mammary artery." *Biomaterials* 30 (2009): 1542-1550.

[2] Yang, Xiaoyuan, et al. "Preparation and evaluation of bicomponent and homogeneous polyester silk small diameter arterial prostheses." *Journal of Biomaterials Applications* (2013) DOI: 10.1177/0885328212472216.

[3] L'Heureux, Nicolas, et al. "Human tissue-engineered blood vessels for adult arterial revascularization." *Nature Medicine* 12 (2006): 361-365.