Mechanical and microstructural evaluation of decellularized porcine thoracic aortas for the development of a biomimetic vascular graft

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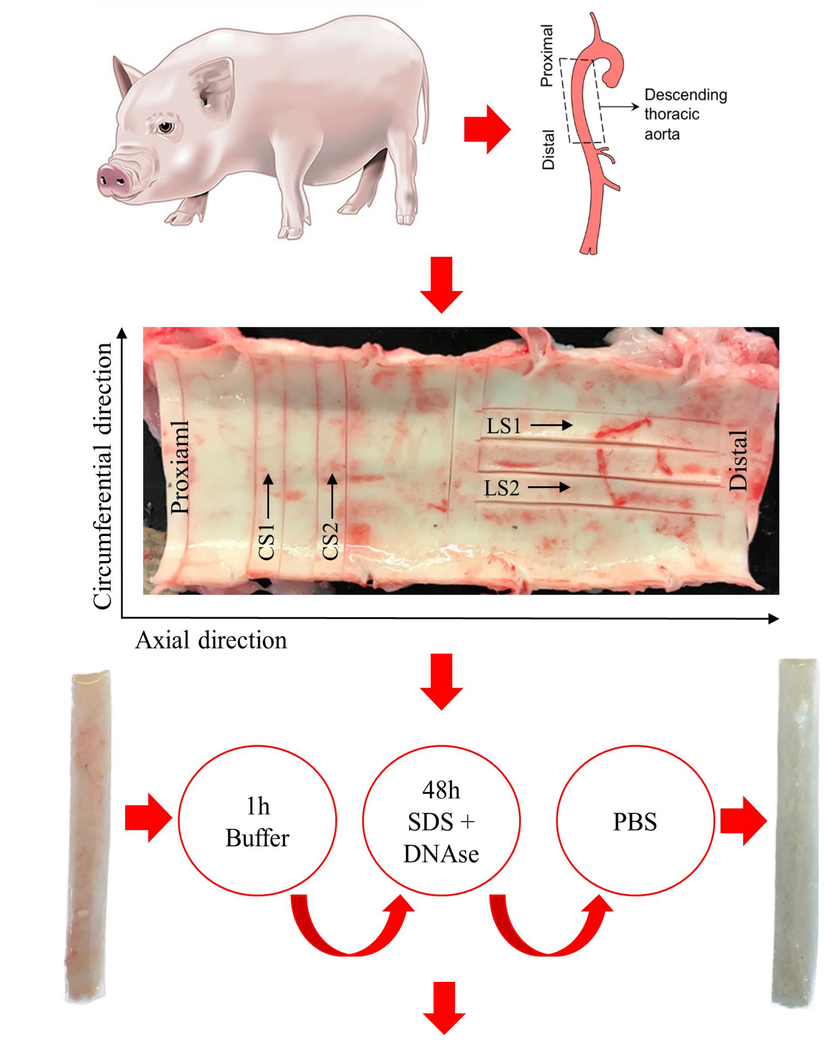
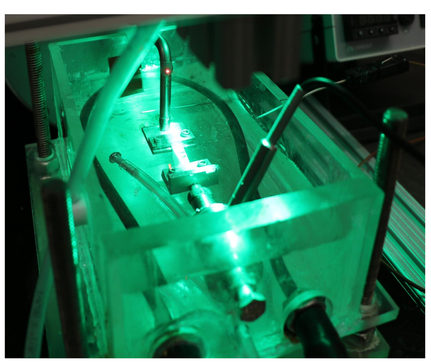
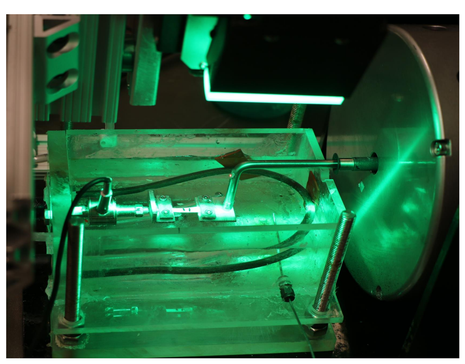
INTRODUCTION

The thoracic aorta has a specific elastic behavior that allows for cyclic diameter expansion of about 10 % during the heart beating for healthy individuals of young age. The stiffness increase of the aortic tissue with age causes a reduction of this expansion [1,2]. This cyclic deformation has the function to accumulate blood during the systole and to release during the diastole, with a positive effect of decreasing the pulsatile nature of the blood flow improving the perfusion to organs. This function is known as Windkessel effect. An increase in the aortic stiffness in addition to a decrease in the Windkessel effect is as a risk factor for clinical hypertension [3]. The grafts that are currently used for aortic repair, after 50 years from their introduction, are showing several complications that are widely documented [4]. The development of biomimetic grafts, mimicking the complex arterial structure, is required urgently. Tissue decellularization aims to remove all cells and cell remnants while preserving the 3D structure of the native Extracellular Matrix, this way the natural conformation and chemical composition of the specific tissue is retained. The objective of the present study is to optimize a decellularization protocol in order to minimize mechanical and structural changes in the ECM.

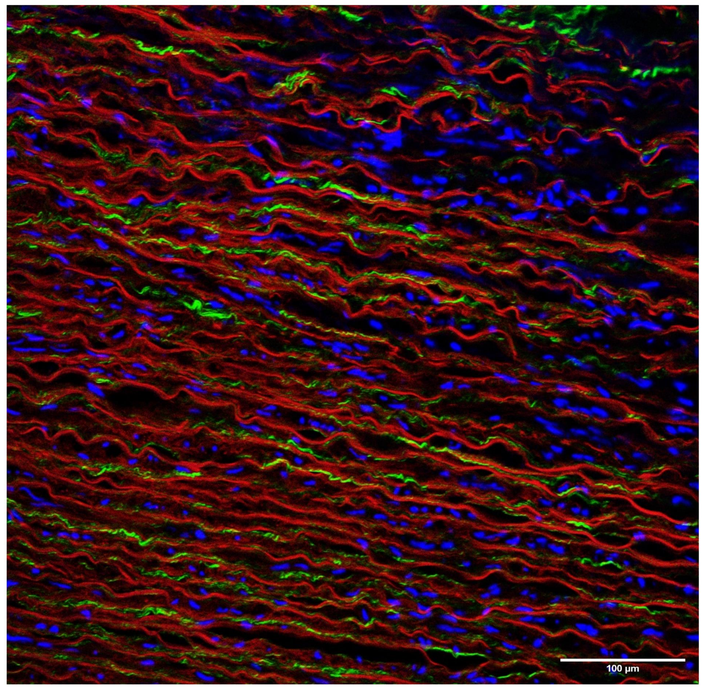
METHODS







RESULTS AND CONCLUSION



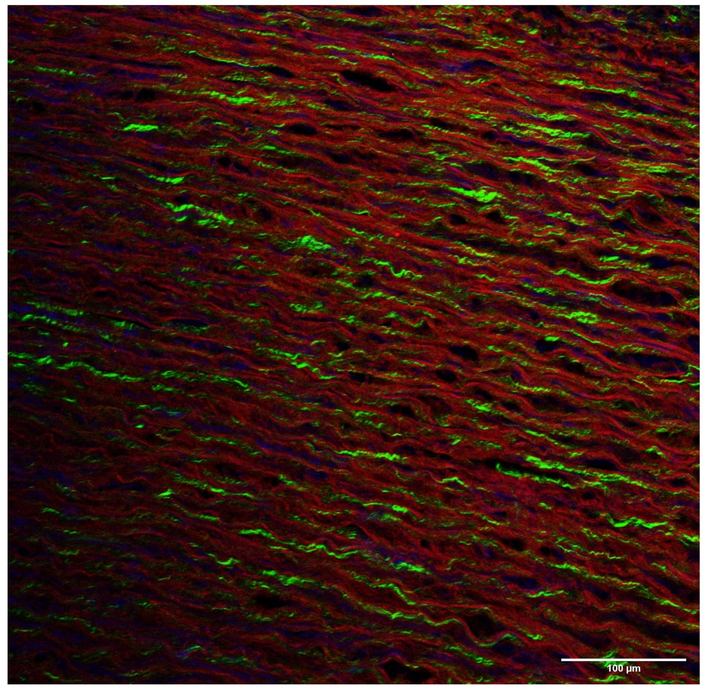
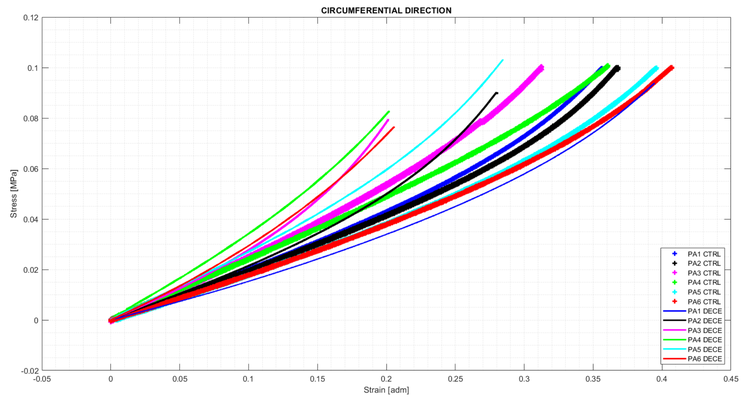


Figure 1 - SHG and TPF signals together with DRAQ5 staining for the control tissue and the decellularized ECM (dECM), sample PA1; the two images show collagen (green), elastin (red) and cell nuclei (blue).



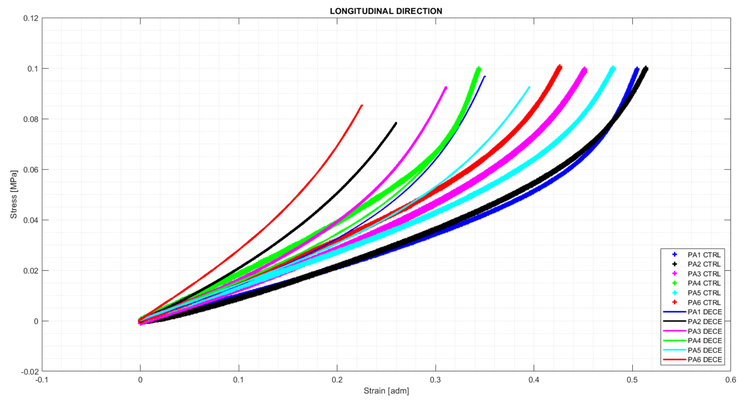


Figure 2 - Quasistatic uniaxial results for six porcine specimen in circumferential and longitudinal direction, for both the control tissue (thick line) and the dECM (thin line).

Sample	PA1	PA2	PA3	PA4	PA5	PA6
Thickness ratio (%) Circ.	88	92	85	85	89	72
Thickness ratio (%) Long.	90	77	95	81	88	83

Table 1 - Thickness ratio (%), defined as the ratio between the thickness of the decellularized strip over the thickness of the original strip.

Decellularization was successfully achieved, Figure 1 shows SHG and TPF signals together with DRAQ5 staining for the control tissue and the decellularized ECM (dECM); it is clear that cell removal was successful and the effect of the decellularization protocol on the structure was minimal, in fact it is possible to see a cross-linked network of collagen and elastin fibers in the treated ECM.

Figure 2 shows quasi-static uniaxial results, the dECM still possesses similar anisotropic hyperelastic behavior compared to the native tissue, with the circumferential direction being stiffer than the longitudinal direction. Moreover, a decrease in compliance can be noted in the vessel after the decellularization process.

This study shows promising results towards the development of a new generation of aortic grafts; decellularization was successful and has the potential to provide “off-the-shelf” scaffolds that mimics the natural tissue ECM and can be then re-populated with cells from the patient. Additional experiments assessing the viscoelastic properties of the dECM are currently being conducted.

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