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Mechanical Properties of Biological Composite Reinforced by Polyester Mesh

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Abstract: The inflation-extension tests were performed with developed hybrid composite manufactured from biological collagenous matrix and reinforced with polyester mesh. The mesh was integrated into biological collagenous matrix in three different configurations. It was shown that we can obtain response from stiff and linear to nonlinear and very compliant depending on the position of the mesh within the matrix.

Keywords: Hybrid Composite; Inflation Tests; Collagen; Polyester Mesh.

1 Introduction

Composite materials are heterogeneous mixtures of two or more homogeneous components, which have been bonded together. In composites, properties or set of properties can be attained which could not have been obtained separately. Many in nature occurring materials can be regarded as composite e.g. bones, blood vessels, woods and others. Man-made composites are used since thousands of years, e.g. straw and natural fibers in bricks, laminated woods, etc. [1].

Over the past few decades, tissue engineering has been focused on development of biological substitutes to restore, maintain, or improve tissue functions. Collagen is the most abundant biological material used for tissue engineering. It is the basic constituent of skin, bones, ligaments and connective tissues. Collagen-based biomaterials have been studied extensively for a variety of biomedical applications, including dialysis membranes, wound dressings and artificial skin. Although native collagen possesses high tensile strength, the chemical treatment necessary for isolation makes the reconstituted collagen very poor in mechanical properties [2, 3]. A possible means to circumvent the problem is to reinforce natural polymer matrix by synthetic fibers or structures. Moreover, the properties of such composite could be modulated through composition of constituents in the material.

In our study, composite tubes were manufactured from biological collagenous matrix and reinforcing polyester mesh. Mechanical properties of this structure were evaluated using inflation-extension tests.

2 Material and Methods

2.1 Material

Tubular samples of hybrid composite were manufactured using extrusion. The polyester mesh was integrated into biological collagenous matrix in three different configurations, see Fig. 1. Samples were placed in physiological solution for two hours before testing. Prior to the mechanical tests, two rings were cut out from the specimen at both ends, and the mean reference dimensions of the samples (external radius, thickness) were determined by means of image analysis of digital photographs, Tab. 1.

Tab. 1: The reference dimensions of tubes for all configurations. Here R_o is the outer radius, H is the overall thickness and H_m is the thickness of polyester mesh, respectively.

configuration	R_0 [mm]	H [mm]	H_m [mm]
A	3.45	0.54	0.14
B	3.49	0.39	0.14
C	3.27	0.43	0.14

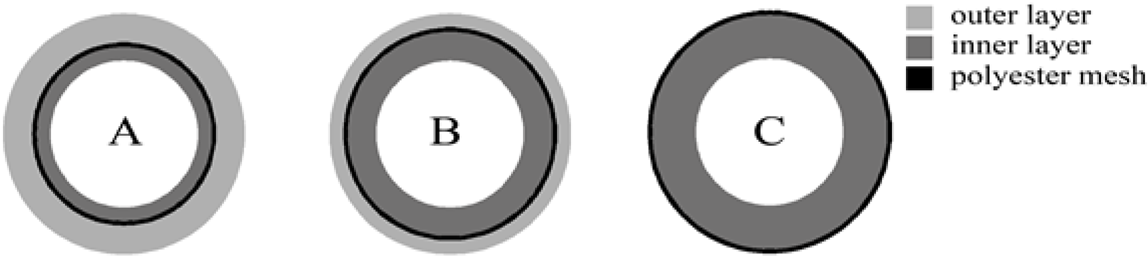

Fig. 1: Configuration of polyester mesh in biological collagenous matrix. A – thicker oter layer, B – thinner outer layer, C – mesh on the outer surface of the sample.

2.2 Methods

Each specimen was mounted in the experimental setup (Fig. 2) and marked with liquid eye-liner. The samples were pressurized in the range from 0 up to ≈ 50 kPa using a motorized syringe (Standa Ltd, Vilnius, Lithuania). The intraluminal pressure was monitored by pressure transducer (Cressto s.r.o, Czech Republic). The deformed geometry was recorded by a CCD camera (Dantec Dynamics, Skovlunde, Denmark). In the data post processing, the radius of the sample and length between marks during pressurization was evaluated by the edge detection algorithm in Matlab (MathWorks, MA, USA).

The longitudinal (λ_z) and circumferential (λ_θ) stretch ratios were computed according Eq. (1). Here L and l is the length between marks in reference and deformed configuration, respectively. R and r is the unloaded and loaded radius of the sample, respectively.

$$\lambda_z = \frac{l}{L} \qquad \lambda_\theta = \frac{r}{R} \tag{1}$$

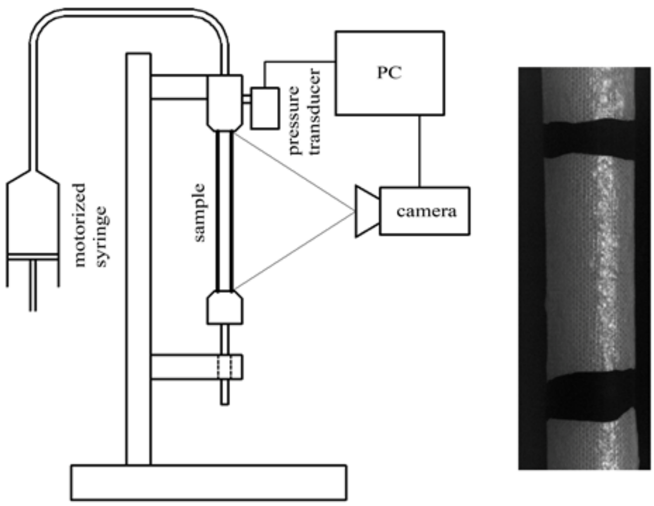

Fig. 2: The experimental inflation-extension test set-up (left) and the picture of the sample from CCD camera (right). The black marks were used to identify the longitudinal deformation during pressurization.

3 Results

The final pressure-stretch curves for all samples are plotted in Fig. 3.

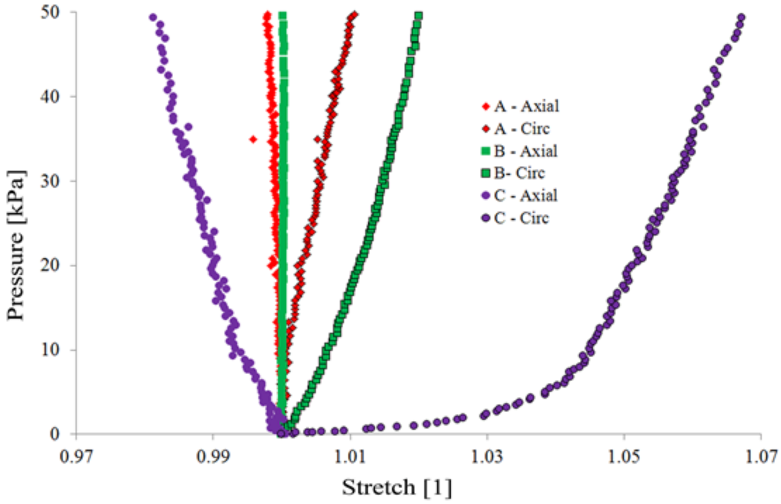

Fig. 3: Pressure-stretch curves for different configurations of polyester mesh in biological matrix (A, B, C). Axial stands for axial and Circ for circumferential direction, respectively.

4 Conclusion

The inflation-extension tests were performed with developed hybrid composite from biological collagenous matrix reinforced with polyester mesh. It was shown that mechanical properties of final composite could be modulated by placing of its reinforced component in the matrix. In comparison: the configuration with thicker outer layer of biological material (configuration A) showed linear and stiff response. If the outer layer was thinner than the inner one (configuration B), we obtained more deformable and almost linear behavior. The last case with polyester mesh placed on the outer surface of composite (configuration C) exhibited highly nonlinear and compliant response.

Acknowledgement

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