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HISTOLOGICALLY-BASED ANISOTROPIC CONSTITUTIVE MODEL OF THE MECHANICAL BEHAVIOUR OF HUMAN ABDOMINAL WALL CONNECTIVE TISSUES

Laure Astruc[1,*], Jean-François Witz[1], Vit Novacek[2], Frédéric Turquier[2], Thierry Hoc[3], Mathias Brieu[1]

[1] Univ. Lille, CNRS, Centrale Lille, FRE 2016 - LaMcube - Laboratoire de mécanique multiphysique multiéchelle, F-59000, Lille, France, mathias.brieu@centralelille.fr
[2] Medtronic, Sofradim Production, 116 avenue du Formans, 01600 Trévoux, France
[3] LTDS, UMR CNRS 5513, Université de Lyon, École Centrale de Lyon, 36 av Guy de Collongue, 69134 Écully Cedex, France

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Abdominal hernia is an abnormal protrusion of the abdominal cavity due to a defect or weakness of the abdominal wall connective tissues. Its repair is one of the most common and frequent surgical operations worldwide, with a high complications rate[1]. A thorough knowledge of the mechanical behaviour is essential to improve this surgical reinforcement. Connective tissues have a highly oriented structure with a spacial weaving of collagen and elastin fibres. Such woven structure has an impact on the mechanical behaviour[2]. This work presents an anisotropic constitutive model based on a histological description of the tissues, with limited number of parameters, only related to the observed microstructure.

Samples of connective tissues were characterized under multi-photon confocal microscope during uni-axial tensile test to link mechanical behaviour and histological properties, namely spatial main orientation, anisotropy amplitude and volume fraction of fibres. To correlate histological and mechanical data, a macromolecular approach in a directional network based on a previous work on pelvic tissues[3], is proposed, integrating an ellipsoid coincident with fibres anisotropy. Based on 3D-image analysis, collagen and elastin phases were accounted with ellipsoids, oriented in the spatial main orientation of fibres and coincident with the orientation dispersion. Nominal stresses are obtained by summation over these ellipsoids.

Directional constitutive model enabled promising description of anisotropic behaviour of anisotropic biological tissues. Assuming fibres properties are similar for every individual, the only information required to model connective tissues anisotropic behaviour are fibres fraction and orientation, provided by image analysis of histological data. This histologically-based model should render numerical simulations of abdominal wall hernia repair more patient-specific and may contribute to improvements of mesh implants.

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