

## MECHANICAL CHARACTERISATION AND CONSTITUTIVE MODELLING OF SOFT TISSUES AND BIORESORBABLE POLYMERS FOR BIOMEDICAL APPLICATIONS

Despite continuous technological progress in surgical practice and biomaterials, postoperative complications associated with soft tissue repair persist and represent unmet clinical needs, with significant consequences for patients in terms of rehabilitation time, functional recovery, and the need for a second surgery.

The BIOMAST Lab (BIO-Materials and STructures Laboratory) at Politecnico di Torino is actively working to translate two innovative polymeric medical devices for soft tissue repair to the market, addressing clinical needs identified by surgeons.

The first device, T-REMEDIE (Tendon REpair MEDical DevIcE), is a biocompatible and biodegradable device designed for tendon repair, aimed at overcoming complications associated with conventional suturing techniques. The second device, T-SURE (Tissue SURgical REpair), is a biocompatible and biodegradable solution developed to enhance outcomes in abdominal hernia repair.

Current efforts in medical device development increasingly rely on high fidelity in-silico modelling of tissue–device systems, enabling an improved understanding of tissue mechanics and tissue–device interactions, while supporting device design and optimisation. Constitutive modelling of soft tissues and biopolymers represents the foundation of these in-silico models. Consequently, the accurate representation of biological tissues using appropriate constitutive formulations is essential for obtaining reliable and meaningful information.

This work focuses on the experimental characterisation and constitutive modelling of soft tissues and biopolymers relevant to the development of these innovative medical devices. The research activity is structured around a systematic workflow in which experimental mechanical tests form the basis for the selection, calibration, and validation of constitutive laws incorporating fibre reinforcement, plasticity, and time-dependent behaviour.

In the context of tendon repair, fibre-reinforced constitutive models are evaluated and developed to capture the intrinsic microstructure and mechanical behaviour of tendons, with particular attention to nonlinear viscous effects. Porcine tendons are investigated as a surrogate animal model for human hand flexor tendons to support the development of the T-REMEDIE device. A visco-hyperelastic constitutive formulation based on an extension of the Generalised Maxwell model is proposed to form the basis of a digital twin of the repaired tendon.

Equine tendons and ligaments are also investigated, motivated by the high incidence of rupture reported in veterinary practice. A visco-hyperelastic formulation based on an extension of the Generalised Maxwell model is proposed, and an alternative constitutive formulation, based on a different assumption of viscous behaviour, is developed and evaluated. Together, these form the first step toward a digital twin of the equine limb to study injury mechanics and support veterinary translation of the T-REMEDIE device.

In the context of abdominal hernia repair through the T-SURE device, the work focuses on the design of the device geometry, experimental testing and validation of the device concept, and the development of manufacturing solutions to realise the first device prototype using medical-grade polymers.

Relevant to both devices, the mechanical behaviour and constitutive modelling of commercially available biopolymers for medical device manufacturing are investigated. Constitutive models are evaluated, and a novel formulation is proposed to capture the evolution of their behaviour during degradation.

The thesis advances the development of the T-REMEDIÉ and T-SURE devices and establishes the basis for high-fidelity in-silico digital twins to improve device performance and patient outcomes. It further contributes to the constitutive modelling of soft tissues and biopolymers by providing formulations capable of capturing their complex mechanical behaviour.