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# Numerical simulation of tensile test on thoracolumbar fascia with mesostructured-level descriptors

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## 1. Introduction

The mechanical characterization of fasciae tissues is crucial in medical and biomechanical research. However, the thoracolumbar fascia (TLF) mechanical behavior, responsible of low back pain (Casato 2019), is underexplored. A better understanding of its properties could improve prevention and treatment of low back pain.

The thoracolumbar fascia is a tissue composed of three layers of collagen fiber bundles embedded in a soft proteoglycan matrix. The superficial layer is formed by crimped collagen fibers, the intermediate layer is formed by straight fibers oriented at a 78° angle to the superficial layer, and a deep layer composed solely of proteoglycan matter (Benetazzo 2011).

Recent *ex vivo* tensile tests on human thoracolumbar fascia have provided experimental force-strain data. This study aims to evaluate the performance of discrete element approaches to model the macroscopic mechanical behavior of the thoracolumbar fascia based on mesostructural knowledge.

## 2. Methods

### 2.1 Geometrical modelling

In this model, only the layers of collagen fibers were considered. These fibers were directly represented, modeled as bonds linking elements with specified diameters. The arrangement of these elements and their diameters reproduced the diameters, respectively 30% and 60% of the sample thickness, and orientations, respectively 0° and 78°, of the collagen fibers bundles.

The proteoglycan matrix was integrated via a second type of mechanical bonds, connecting nodes from different fibers via Delaunay triangulation.

### 2.2 Mechanical modelling

Collagen bonds were modeled as non-linear springs, characterized by an elasticity modulus of 2130 MPa (Kato 1989). The crimped superficial fibers were assigned a bi-linear behavior with a defined slack threshold. Below this threshold, the elasticity modulus was considered zero, while above the threshold, the elasticity modulus was set at 2130 MPa. The slack thresholds for the superficial fiber springs were randomly distributed following a truncated normal distribution. Key parameters, such as the mean, standard deviation, and maximum value of this distribution, played a crucial role in describing the mechanical behavior. The matrix links between fibers were modeled with elastic beam behavior, with an elasticity modulus of 0.1 MPa and a 0.3 Poisson's ratio. To prevent fibers overlap, contact detection between different collagen fibers was enabled.

The simulations were conducted using the open-source software GranOO (Granular Object Oriented, [www.granoo.org](http://www.granoo.org), Mechanics Institute of Bordeaux (I2M)). The model was applied to perform uniaxial tensile tests on rectangular-shaped domains.

### 2.3 Simulation parameters

Several uniaxial tensile tests were conducted along the direction of the superficial fibers to investigate the

impact of the slack distribution on the tissue’s mechanical behavior. The sample size was .

Additionally, the model was employed to simulate various scenarios:

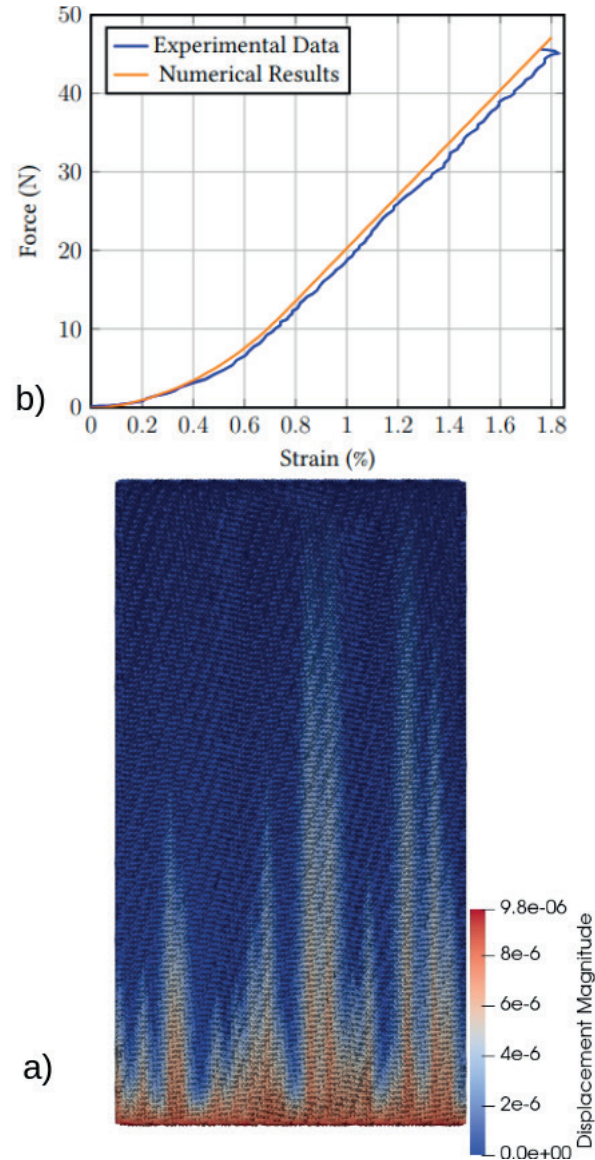
- Comparison with an experimental uniaxial tensile test (Creze 2025) along the direction of the superficial fibers.
- Simulated uniaxial tensile test in the direction of the superficial fibers, with significant deformation to achieve large strain.
- Simulated uniaxial tensile test in a direction orthogonal to the superficial fibers.
- Simulated uniaxial tensile test to tissue rupture, using a sample with an initial crack.

### 3. Results and discussion

The simulated sample exhibited a heterogeneous displacement field. (Fig.1 a). The displacement differences corresponded to the different fibers slacks. A fiber with a high slack value would easily deform at small strain. The displacement field at small strain represent the slack distribution over the collagen bonds. This highlighted the ability of the model to capture local data during the simulations. Computing local stress and stress is an essential part of a rupture numerical model.

In terms of experimental data comparison, the numerical model matched the experimental results (RMSE = 0.13N), despite only calibrating the slack distribution parameters. The model also neglected the deep layer of the tissue, which may account for some of the observed differences. Furthermore, the mesostructure—specifically the fibers orientations and diameters—was sourced from literature rather than being experimentally measured for the studied sample.

Although experimental data for comparisons were lacking, the other simulations provided valuable insights. The large deformation test revealed contact interactions both between different layers and within the layers themselves. The orthogonal tensile test significantly altered the stressed bonds and the overall tissue behavior. In the rupture test, the tissue exhibited a plausible crack propagation pattern. As the bonds were breaking when reaching maximum elongation, the load was redistributed over the nearest bonds leading to new bonds breaking and to an overall crack propagation.



**Figure 1.** (a) Displacement magnitude of the links for a global 0.03% strain. (b) Comparison between numerical and experimental data for a uniaxial tensile test

### 4. Conclusions

This study presents a numerical model of the thoracolumbar fascia based on a mesostructural description. The model provides a range of applications, including uniaxial tensile testing and crack propagation analysis.

### Conflict of Interest Statement

None.

## Contributor Roles

AL: Methodology, Writing original draft, investigation;  
CV: Writing review and editing; SL: Writing review  
and editing; JG: Writing review and editing

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