P043: Local adaptation of bone micro-structure and canal network to tendon insertion investigated by image-based micro-FE simulations

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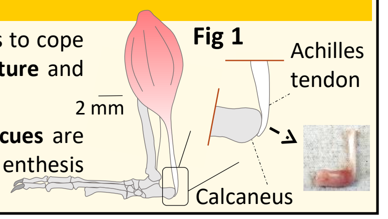
INTRODUCTION

- Tendons anchor to bone through a **multi-material region called enthesis**, showing several strategies to cope with the challenging task of joining dissimilar tissues. Less understood is whether **bone micro-structure** and **fibrocartilage** covering it also display specific features to manage the load received from the tendon.

- Bone micro-structure dictates **stress distribution**, also at the enthesis location. **Local mechanical cues** are believed to play a crucial role in several pathologies and injuries of the attachment region (including enthesis inflammation and avulsion fractures).

Fig 1



I. BONE MICRO-STRUCTURE

METHODS

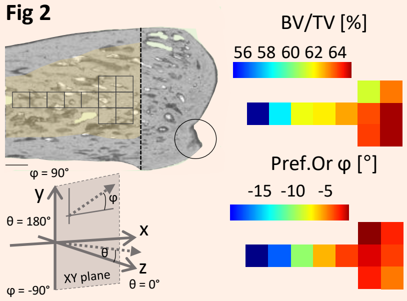
Quantitative analysis [*Matlab, CTAn and Avizo*] of **micro-CT scans** from n = 5 Sprague Dawley rats, at low (5 µm) and high (1.25 µm) resolution [*Bruker SkyScan 1272*].

RESULTS

Scale bars: 500 µm

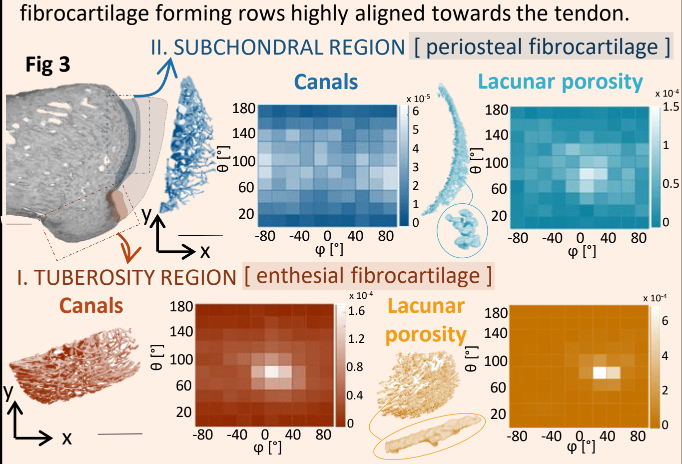
- **Trabecular micro-structure:** clear gradient along the cranio-caudal direction but none along the dorso-ventral direction → trabecular network not significantly influenced by the tendon insertion.

Fig 2



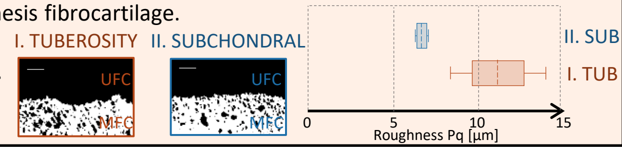
- **Canal network** and **lacunar porosity:** significantly oriented canal network, as well as fibrochondrocytes of the mineralized fibrocartilage forming rows highly aligned towards the tendon.

Fig 3



- Mean **roughness** (root mean square P_q): **65%** higher at the interface between unmineralized (UFC) and mineralized (MFC) enthesis fibrocartilage.

Fig 4



II. BONE MECHANICAL MICROENVIRONMENT

METHODS

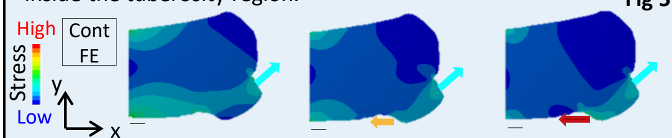
Continuum (cont FE) and micro-finite (µFE) element model based on micro-CT scans in two dimensions, down to a resolution of 1.25 µm [*Ansys*] and three dimensions on a rescaled 20 µm model [*Parosol*].

RESULTS

Scale bars: 500 µm

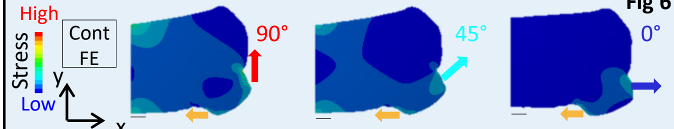
- Increased **force intensity** at the ligament side (equivalent to human plantar fascia): progressive concentration of stresses inside the tuberosity region.

Fig 5



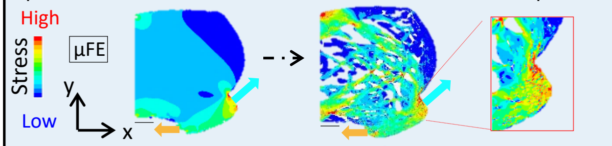
- Stress level in the tuberosity region: robust against the changes in the **force orientation** at the Achilles tendon.

Fig 6



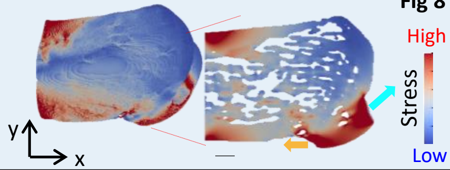
- Inclusion of **micro-porosity**: induction of a more complex pattern and stress concentrations around the micro-pores.

Fig 7



- First **3D results**: similar stress concentration within the tuberosity, but higher stress level.

Fig 8



MAIN CONCLUSIONS & OUTLOOK

- Site-dependency on **surface roughness, canal and fibrochondrocytes lacunae orientation** indicates that specific loading conditions may be associated with dedicated fibrocartilage types, but also adapted bone micro-porosity.
- Tendon loading induces a **non-trivial stress pattern** within bone that could not be predicted with a simple cantilever beam model.
- **Mineral content** and **mechanical properties** at the two sites of interest will be investigated (in collaboration with the Ludwig Boltzmann Institute of Osteology in Vienna, Austria).

Acknowledgments: Alexandra Tits is a FRIA (Fund for Research Training in Industry and Agriculture) grantee (n°5129219F)