Examining individual variation and deformation dependence of growth plate tissue mechanics

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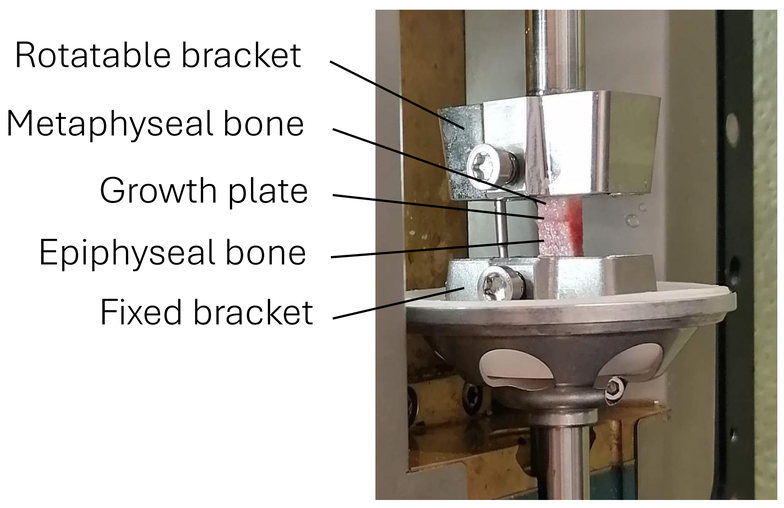
Introduction

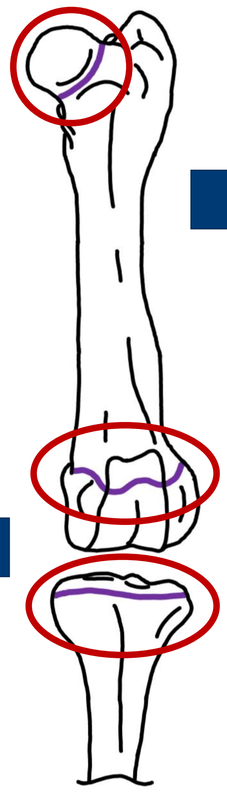
- Finite element analyses are used to evaluate mechanical stresses in the growth plate (GP), which depend on the material properties.
- This study performed shear tests to investigate material properties, which have been poorly studied until now.

Mechanical Testing

Specimen:

- 5 porcine individuals





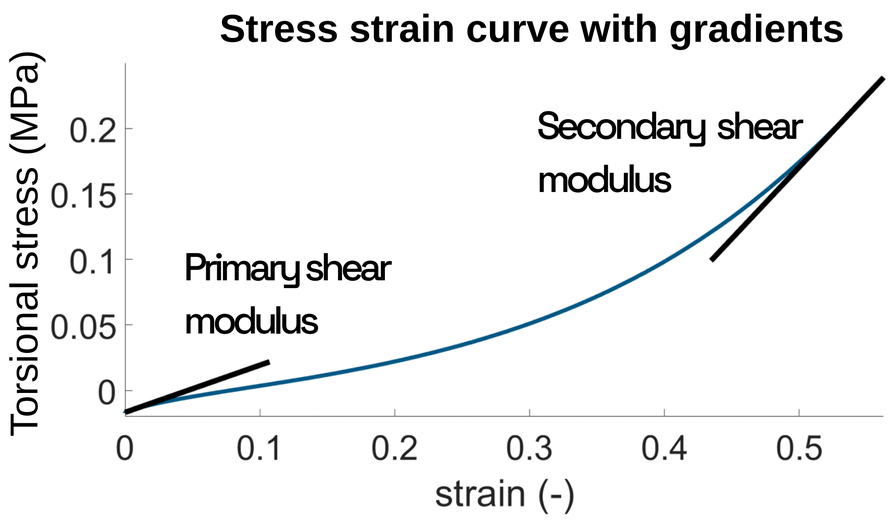
Test protocol:

- Cyclic deformation
  - shear rates of 0.04°/s, 0.2°/s, or 0.5°/s
  - maximum deflection angle of 8° to 10°
- Continuously increasing angle up to 25° until failure

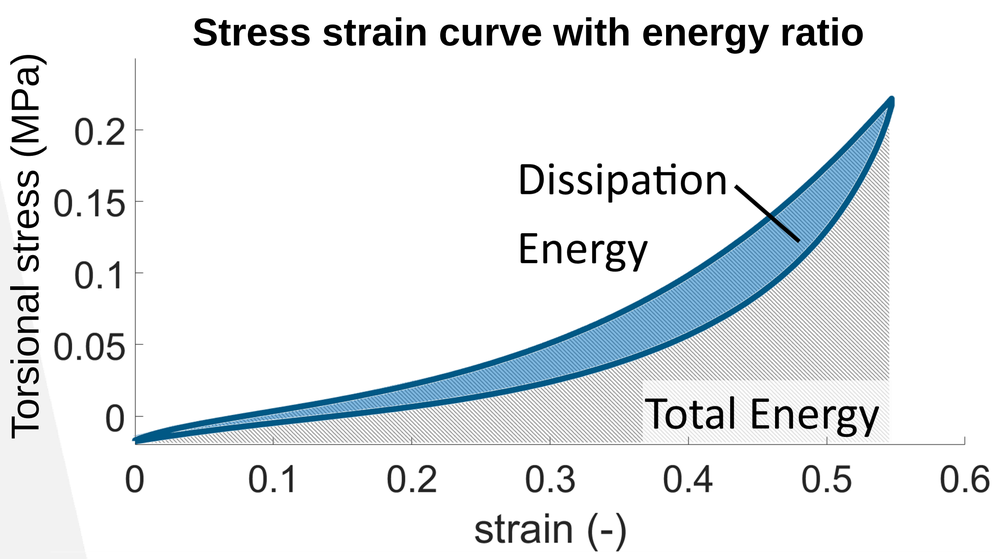
Material Properties

- Evaluation with MATLAB, Version R2023a (MathWorks, US-MA)

Elastic Properties:



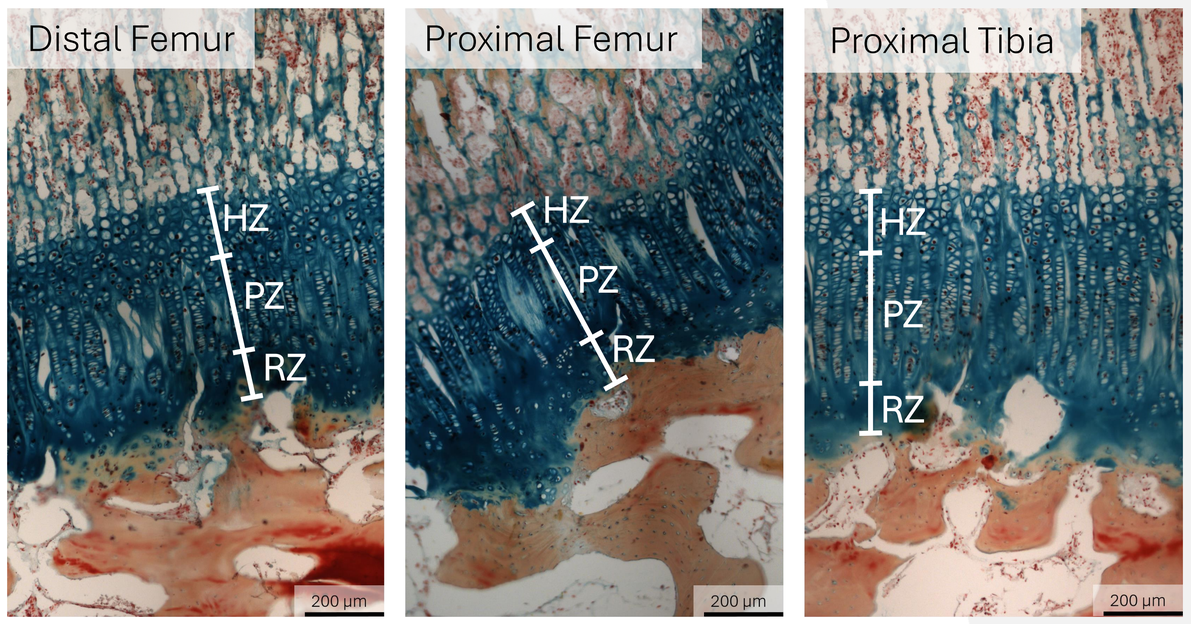
Viscoelastic Properties:



$$Energy\ ratio = \frac{Dissipated\ strain\ energy}{Total\ strain\ energy}$$

Histology

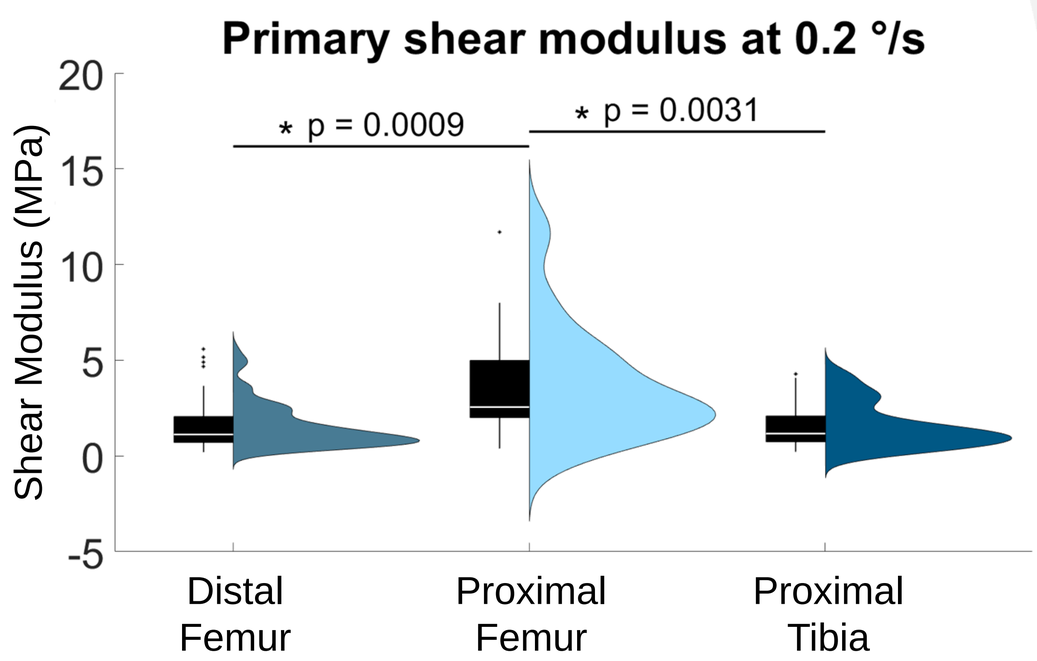
- MOVATs pentachrome staining

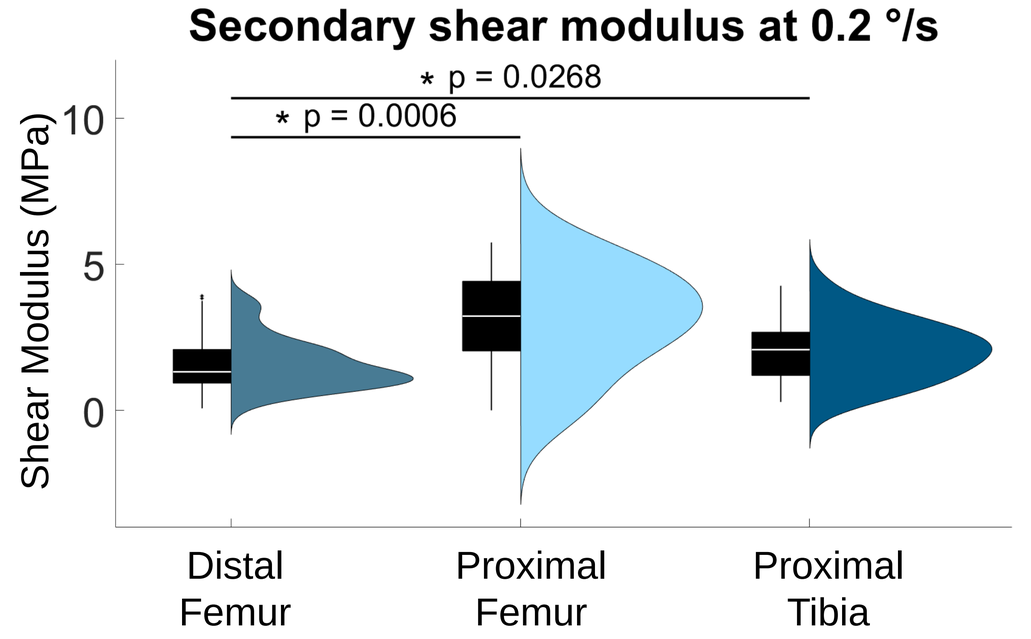


HZ – Hypertrophy Zone | PZ – Proliferative Zone | RZ – Resting Zone

Results

- No clear differences of evaluation parameters between individuals
- There is a low to moderate negative correlation between the thickness of the hypertrophic zone and the two shear moduli, which becomes more prevalent with faster testing speeds.
- The energy ratio is smaller for samples tested fastest.





Discussion

- Material properties of growth plate cartilage are not linear elastic.
- Next step will be to identify an appropriate constitutive relation for the purpose of finite element analyses.