

# Fabric-Elasticity Property Relationships of the Human Cortical Femur

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## ABSTRACT

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## 1. Introduction

Bone is a hierarchical material...

### 1.1. Bone structure

- Bone composition
- Mineralised collagen fibrils
- Lamellar bone
- Osteon
- Cortical bone
- Trabecula
- Trabecular bone
- Full bone

### 1.2. Mechanical testing

- Nanoindentation
- Resonant ultrasound spectroscopy
- Full section compression

### 1.3. Imaging

- Micro-computed tomography
- High-resolution peripheral quantitative computed tomography
- Computed tomography

## 1.4. Bone Properties Estimation

- Micro finite element analysis
- Density and fabric
- Homogenised finite element analysis

The aim of the present study is to investigate the influence of the bone matrix properties and microstructure on the mechanical properties of human bone. The relationships between density, fabric and mechanics are presented from the bone matrix (bone of full density) down to the low density of trabecular bone with a strong focus on the cortical bone. Additionally to relationships description, the objective is to provide material constants for bone properties estimation.

*Abbreviations:* ROI, region of interest;  $\mu$ CT, micro-computed tomography;

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## 2. Material and Methods

### 2.1. Theoretical Model

- Density-elasticity relationships
- Fabric-elasticity relationships

### 2.2. Bone Experimental Properties

#### Lamellar bone

- Nanoindentation data
- Virtual fabric

#### Cortical bone

- Samples
- Micro-CT
- RUS data

#### In the present study:

- Downsampling factor 2
- $16 \times 1 \text{ mm}^3$  Relationships
- Isotropic vs transverse isotropic material
- Average  $\mathbb{S}$  per sample

#### Trabecular bone

## 3. Results

### 3.1. Sample Fabric

### 3.2. Fit to model

### 3.3. Comparison to RUS

### 3.4. Effect of Porosity

## 4. Discussion and Conclusion

### Declaration of competing interest

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

### Funding

This work was funded by the Swiss National Science Foundation (SNSF), grant number 200365.

### Data availability statement

The data that support the findings of this study are available on request. The data are not publicly available due to privacy/ethical restrictions. The scripts used for the analyses performed in the present study are available on Github: <https://github.com/artorg-unibe-ch/FABTIB>

### Research ethics

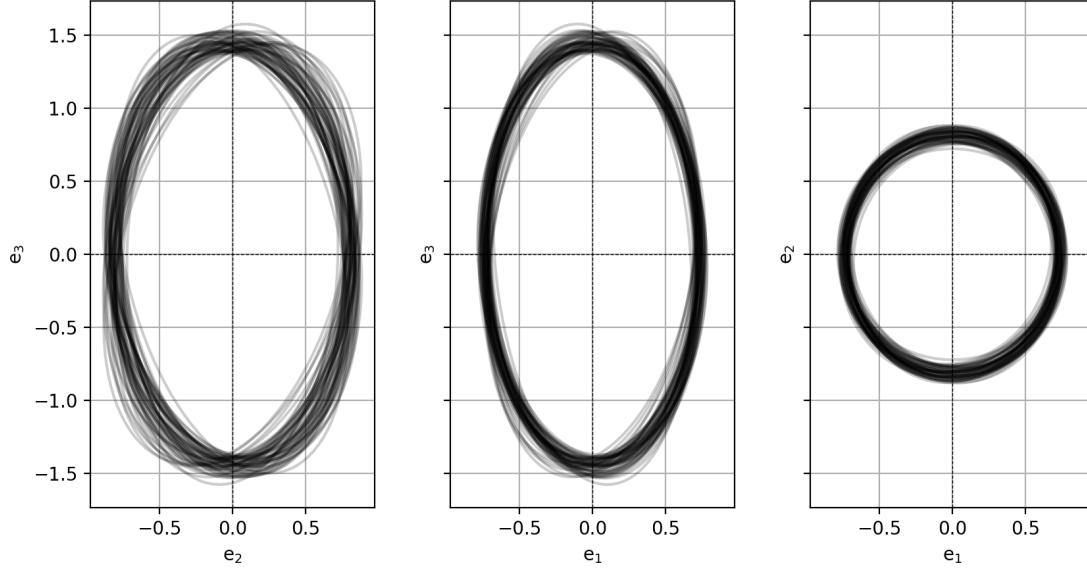
We further confirm that any aspect of the work covered in this manuscript that has involved human patients has been conducted with the ethical approval of all relevant bodies and that such approvals are acknowledged within the manuscript.

### CRedit author statement

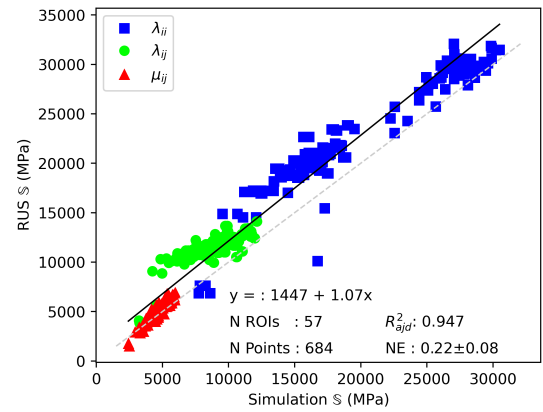
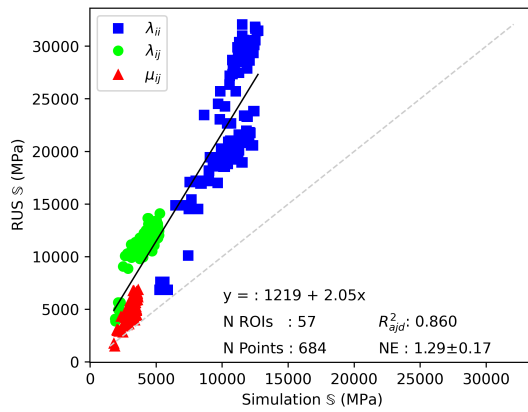
**Mathieu Simon:** Data Curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing - original draft. **Philippe Zysset:** Conceptualization, Funding acquisition, Methodology, Project administration, Resources, Supervision, Validation, Writing - review and editing.

## References

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Material	$\lambda_0$	$\lambda'_0$	$\mu_0$	k	l	R <sup>2</sup>	NE
Isotropic	5170 [4982 - 5359]	5092 [5055 - 5129]	3860 [3825 - 3895]	2.13 [2.07 - 2.18]	0.08 [0.07 - 0.09]	0.99	0.04
Transverse isotropic	11150 [10761 - 11540]	11017 [10921 - 11114]	6158 [6091 - 6225]	2.20 [2.14 - 2.27]	0.42 [0.41 - 0.43]	0.99	0.05
Isotropic	4660 [4385 - 4936]	4590 [4541 - 4638]	3479 [3428 - 3531]	1.0	0.09 [0.07 - 0.11]	0.96	0.07
Transverse isotropic	9978 [9456 - 10504]	9860 [9745 - 9975]	5511 [5422 - 5602]	1.0	0.42 [0.40 - 0.44]	0.95	0.08
Isotropic	5601 [4111 - 7116]	5516 [5227 - 5821]	4181 [3909 - 4472]	2.0 [1.61 - 2.38]	1.0	0.61	0.40
Transverse isotropic	11649 [10266 - 13048]	11511 [11173 - 11858]	6434 [6199 - 6678]	2.26 [2.05 - 2.48]	1.0	0.85	0.25



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