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Fabric-Elasticity Relationships in Cortical Bone

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Material

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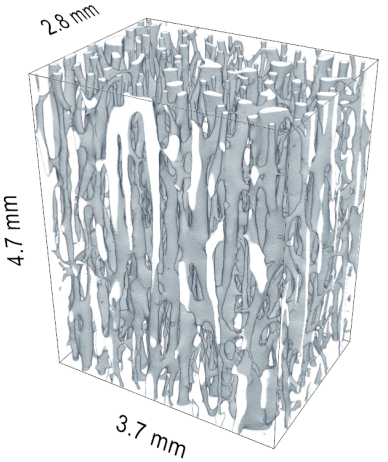
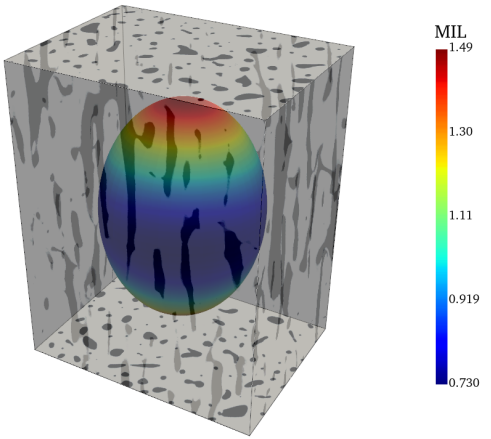
Data

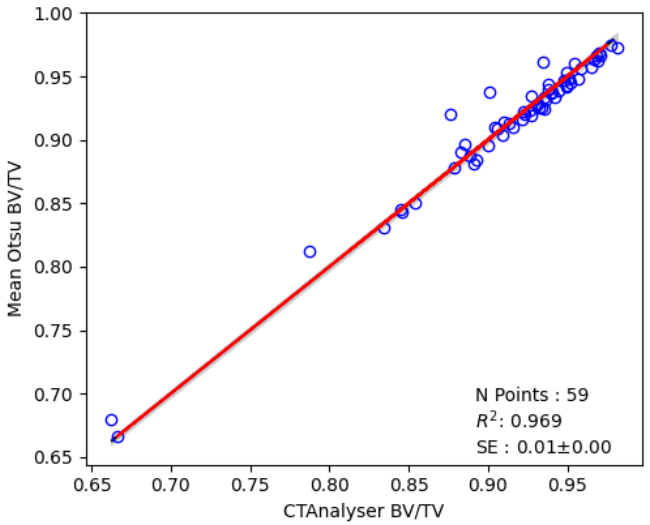
- 59 scans
- 6.5 µm voxel size
- RUS measurements
- CTAnalyser



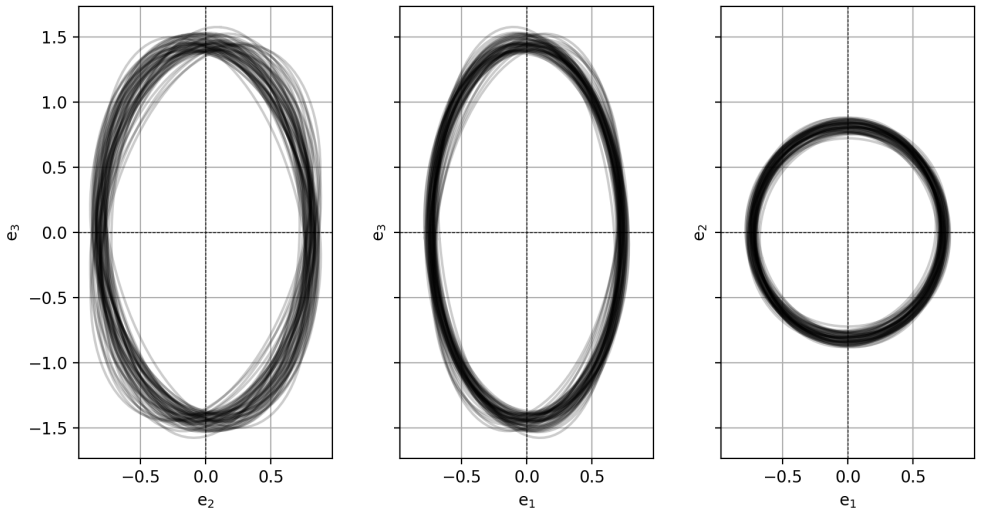


Segmentation

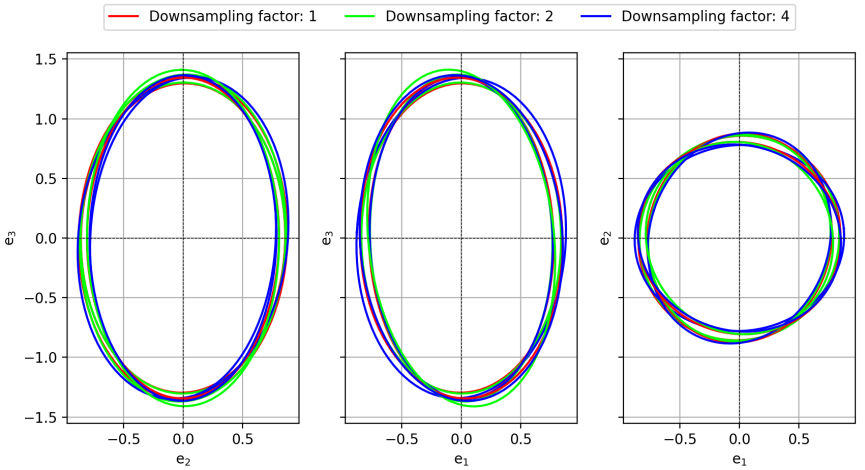
Mean Otsu threshold

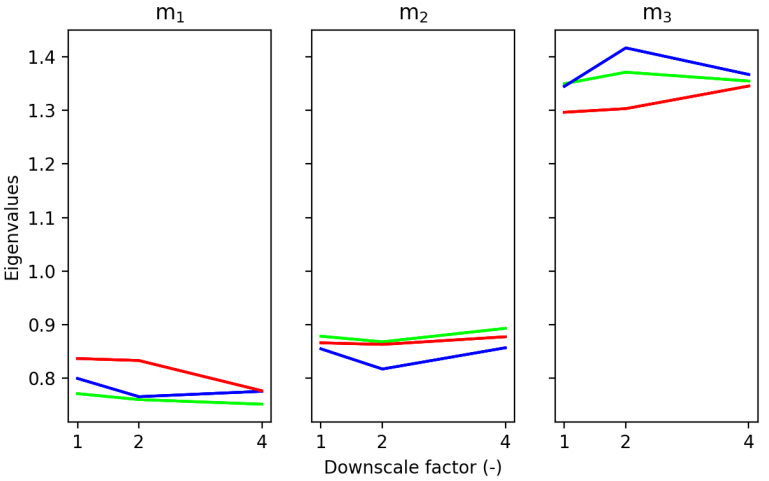


Fabric distribution

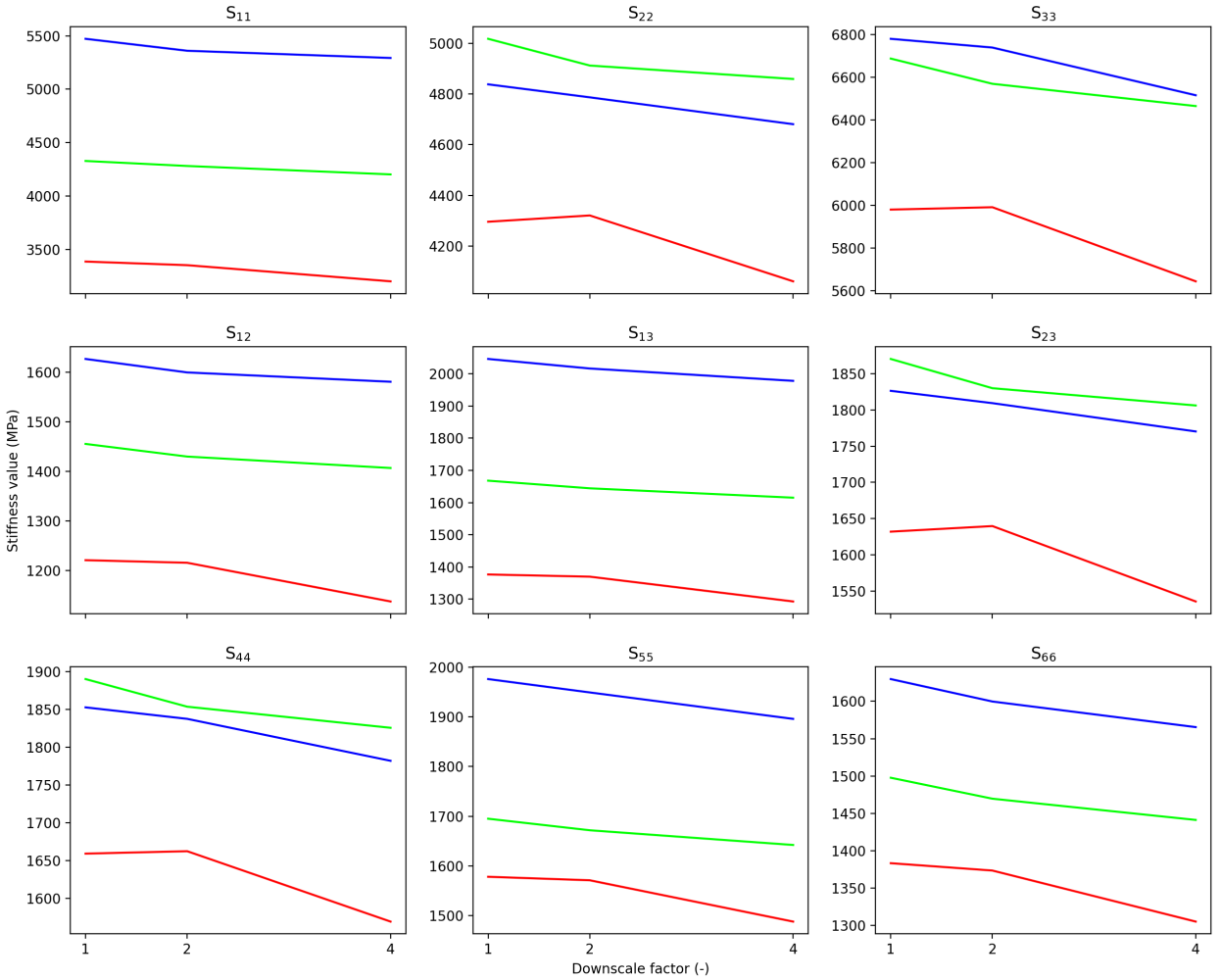


Resolution Effect - Fabric

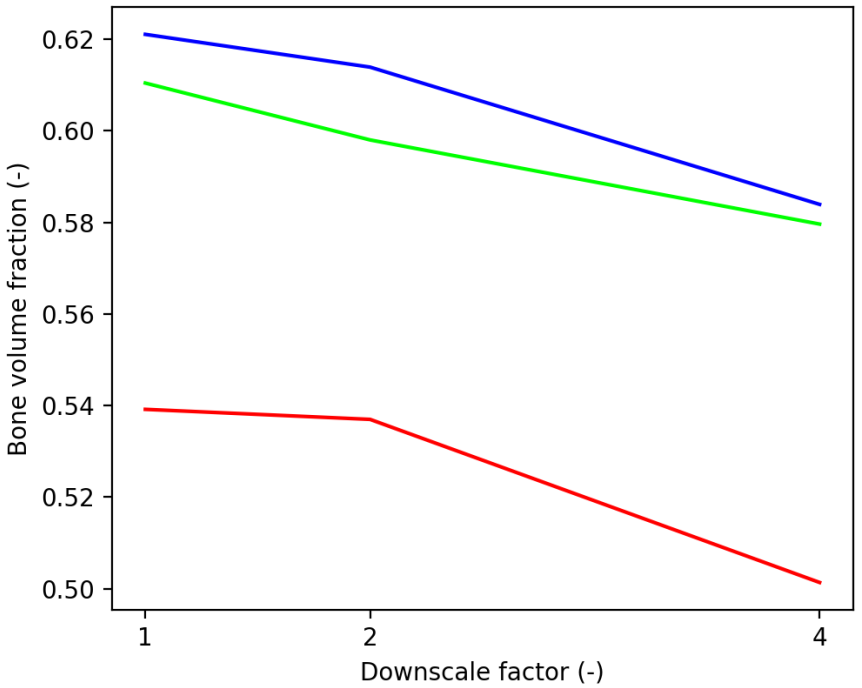


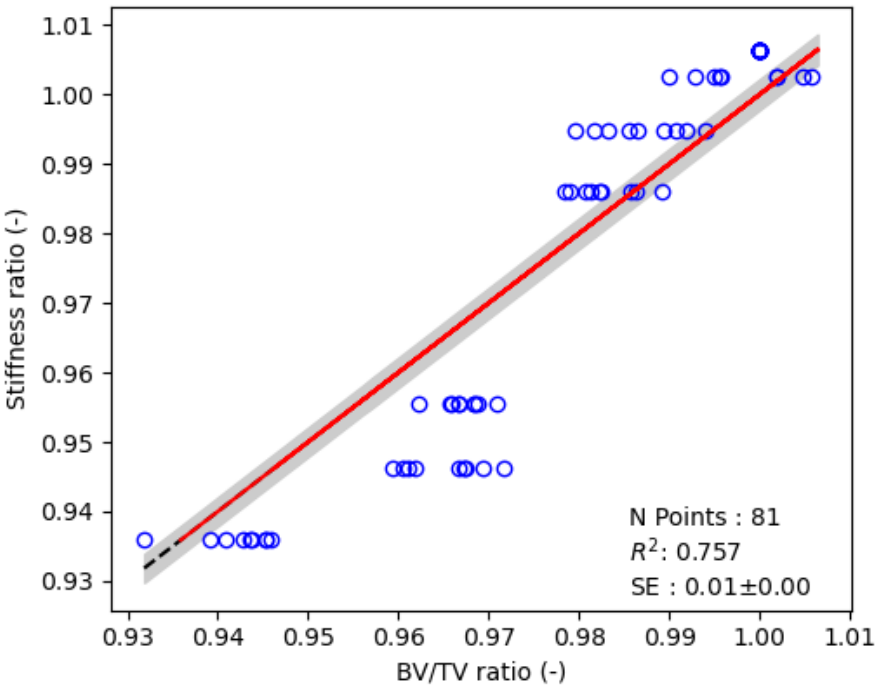


Resolution Effect - Elasticity



Resolution Effect - Elasticity II





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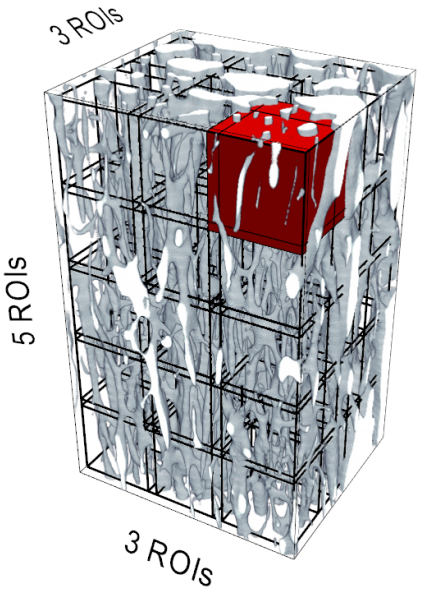
Convergence Study

Setup

- 1mm ROI side length
- 3x3x5 ROIs
- 65 µm margin
- Groups of 1, 2, ..., 45 ROIs

→ ~2^{45} possibilities

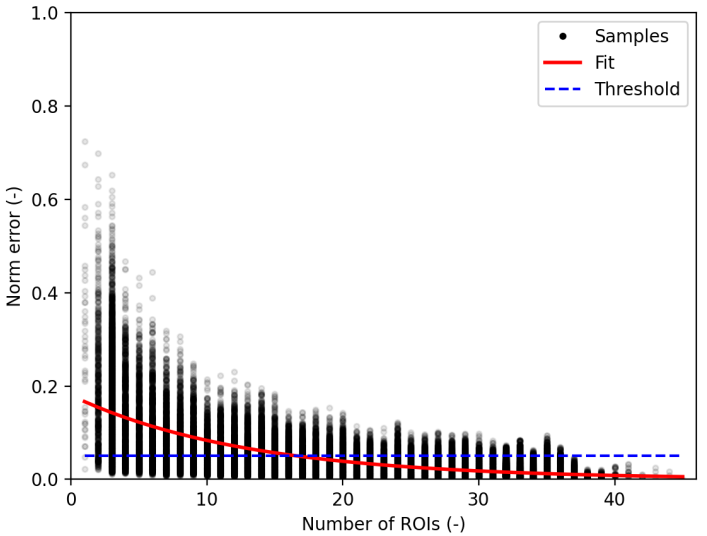


Convergence Study

Sampling

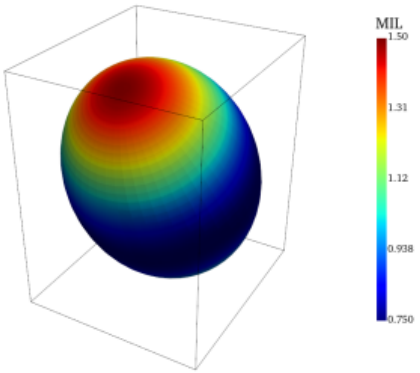
- Balanced clustering
  → Linear sum assignment
  → $216*10^6$ possibilities
- N samples = 1000
- Norm Error
- Threshold = 0.05

→ 15-16 ROIs



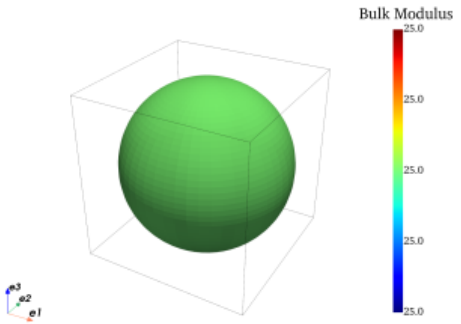
Material Effect

Structure

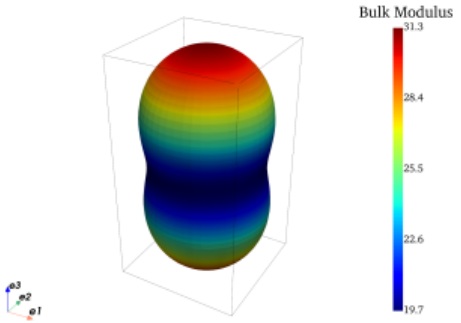


Fabric

Material

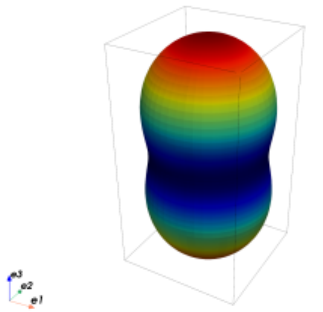


Isotropic



Transverse Isotropic

Mechanics

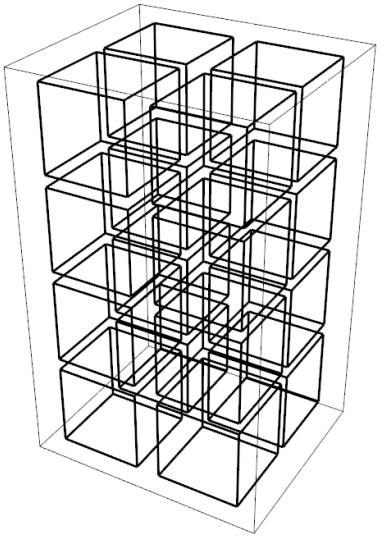


Transverse Isotropic

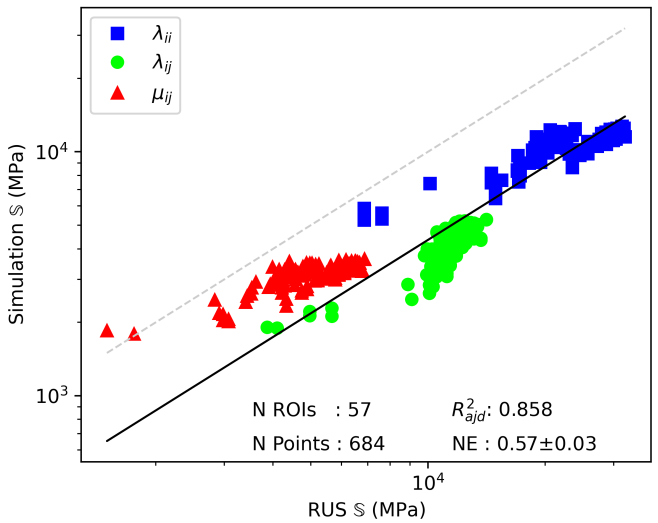
Homogenization

Setup

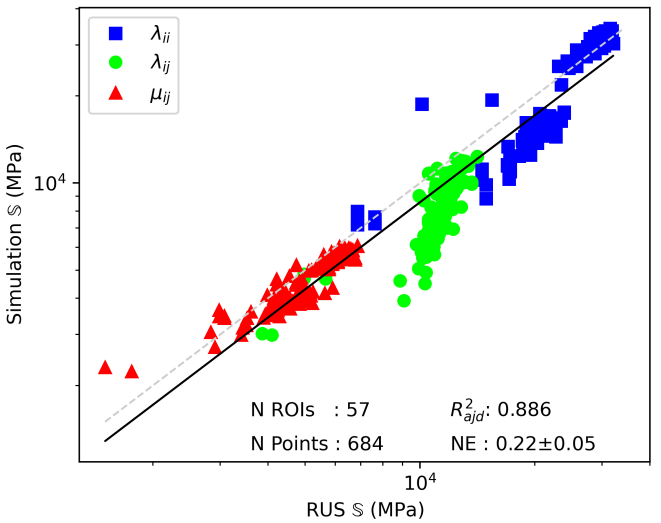
- Downsampling factor: 2
- 16x1mm^3 ROIs
- Isotropic vs transverse
- Mean $\mathbb{S}$ / Sample



Simulations vs RUS

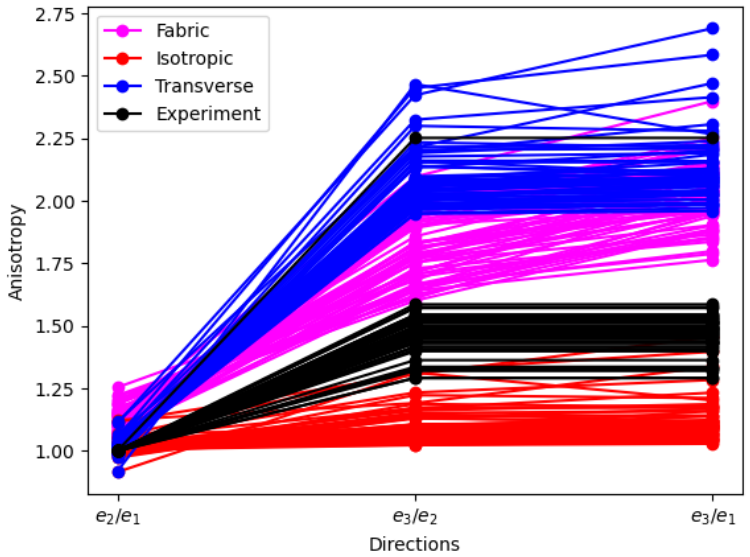


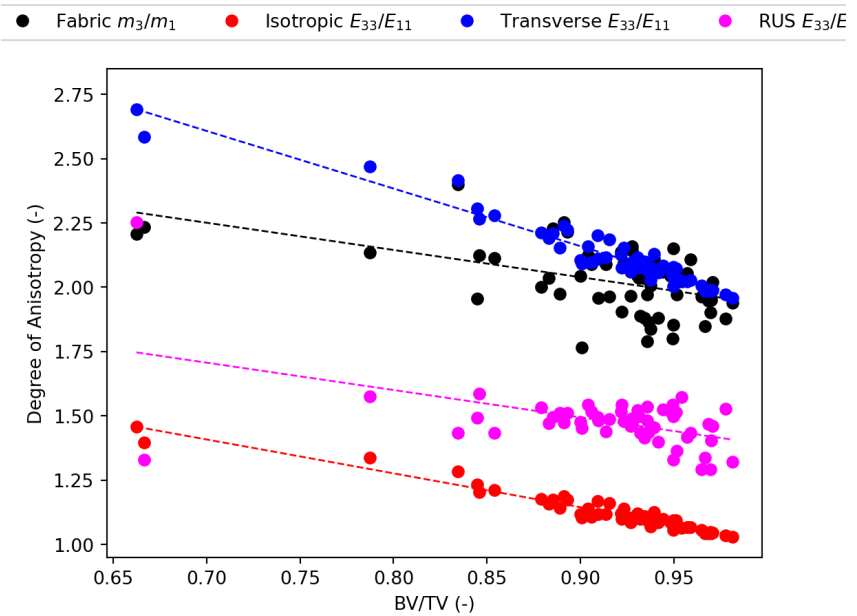
Isotropic Material



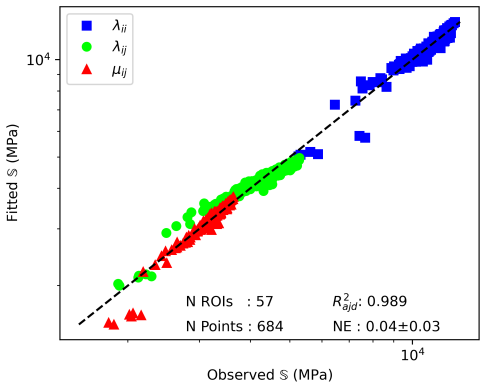
Transverse Isotropic Material

Anisotropy

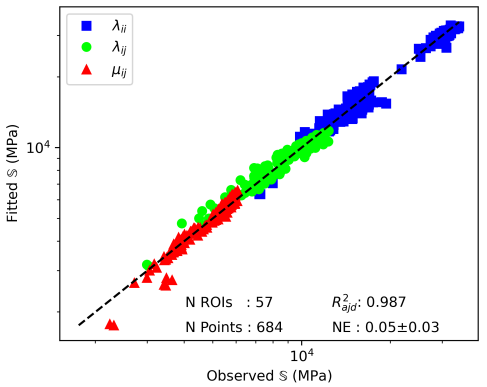

Fabric
Isotropic
Transverse
Experiment
Anisotropy
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
e_2/e_1
e_3/e_2
e_3/e_1
Directions


Fabric m_3/m_1
Isotropic E_{33}/E_{11}
Transverse E_{33}/E_{11}
RUS E_{33}/E
Degree of Anisotropy (-)
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.65
0.70
0.75
0.80
0.85
0.90
0.95
BV/TV (-)

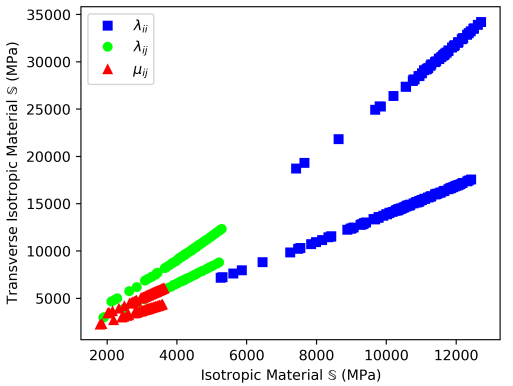
Homogenization



Isotropic



Transverse



Comparison

Comparison with Trabecular Bone

$$\mathbb{S}_{Ts} = \mathbb{S}_T / ||\mathbb{S}_T|| * ||\mathbb{S}_I||$$

Study	Bone type	Resolution	λ_0	λ_0'	μ_0	k	l	DA
Gross et al.	Trab.	18	4609	3692	3738	1.60	0.99	1.67
Panyasantisuk et al.	Trab.	36	3841	3076	3115	1.60	0.99	1.54
Simon et al	Trab.	61	2738	1662	2187	1.60	0.99	1.99
Present study	Cort. ($\mathbb{S}_I$)	13	5389	5307	4023	1.60	0.99	2.02
Present study	Cort. ($\mathbb{S}_{Ts}$)	13	5574	5511	3077	1.60	0.99	2.02

Comparison l Exponent

Reference: Transverse isotropic

- $\mathbb{S}_{Is} = \mathbb{S}_I / ||\mathbb{S}_I|| * ||\mathbb{S}_T||$
- $\lambda_0 = 11096$
- λ_0'$= 10970$
- $\mu_0 = 6124$
- $k = 2.18$

Matrix	Isotropic	Transverse
l	-0.04	0.46
95% CI Low	-0.12	0.39
95% CI High	0.04	0.52