Differences In Cortical Pore Morphology In Regions Of Tension And Compression In The Femoral Diaphysis

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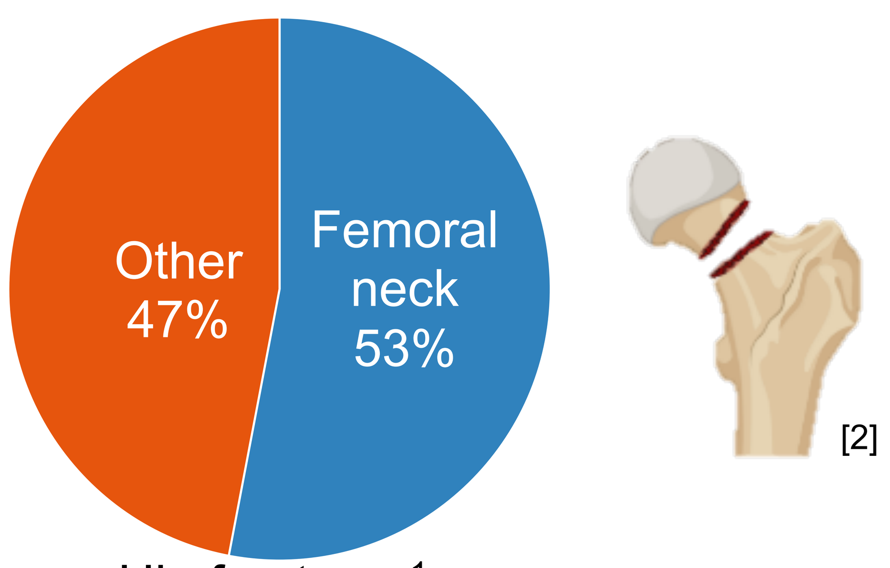
TISSUE BIOMECHANICS LABORATORY

1. Clinical motivation

- Femoral neck fractures continue to persist in elderly populations



Hip fractures[1]

- There is no diagnostic measure that can predict fracture[3]
- Abnormal remodeling of cortical bone is related to fractures and motivates studies to assess pore microstructure[4,5]
- The sensitivity of pore microstructure to the mechanical microenvironment is unclear[6]

Will new measures of porosity provide additional insight?

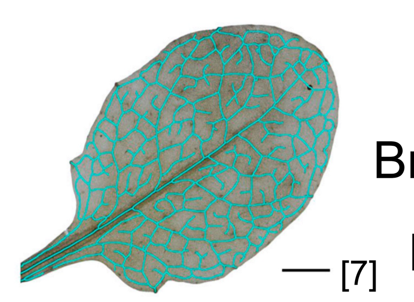
Objectives

(1) Identify new measures of pore morphology

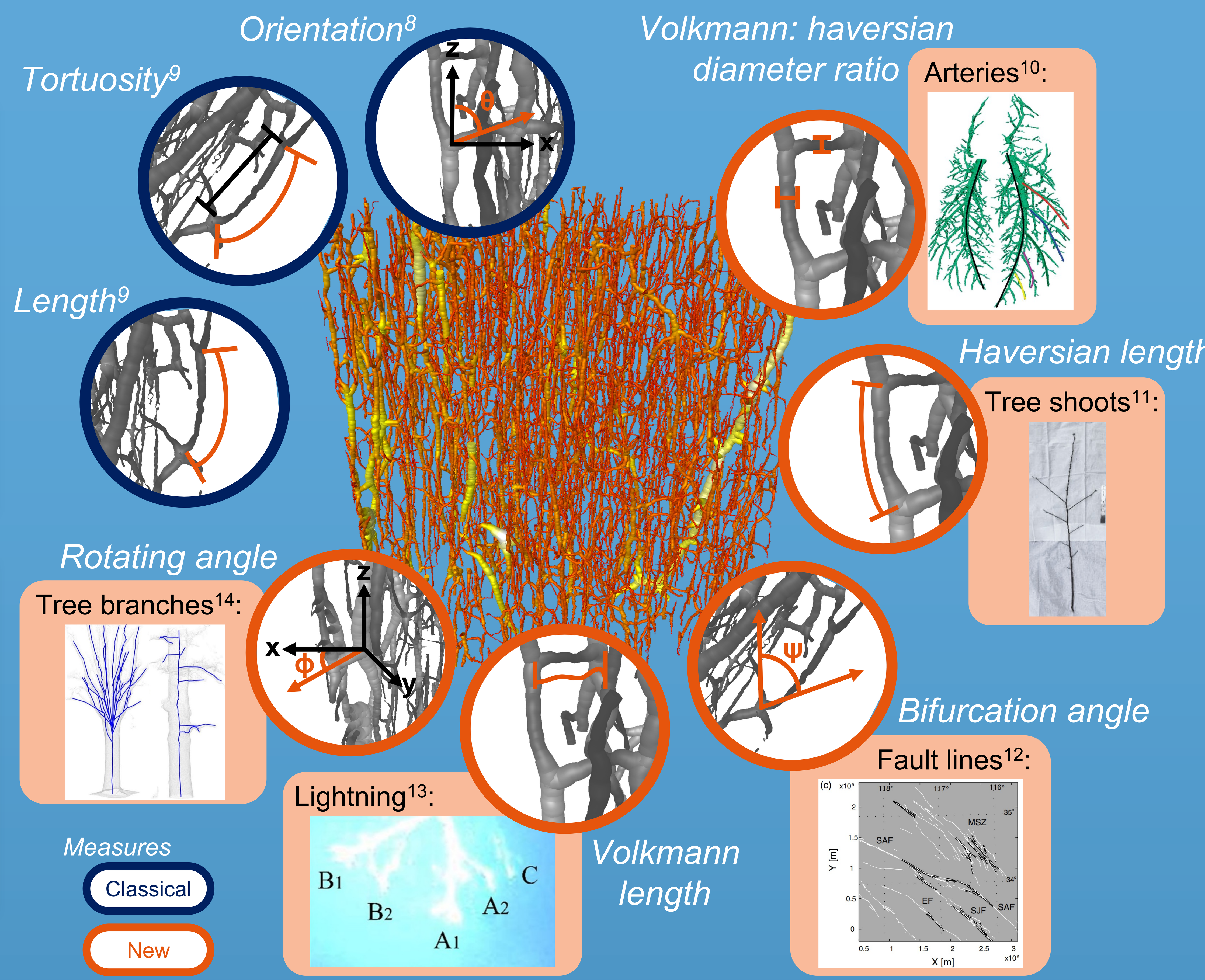
(2) Evaluate cortical pore morphology in regions known to be loaded in tension or compression

2. New measures of pore morphology identified

Branching structures from other scientific fields translated to bone terminology



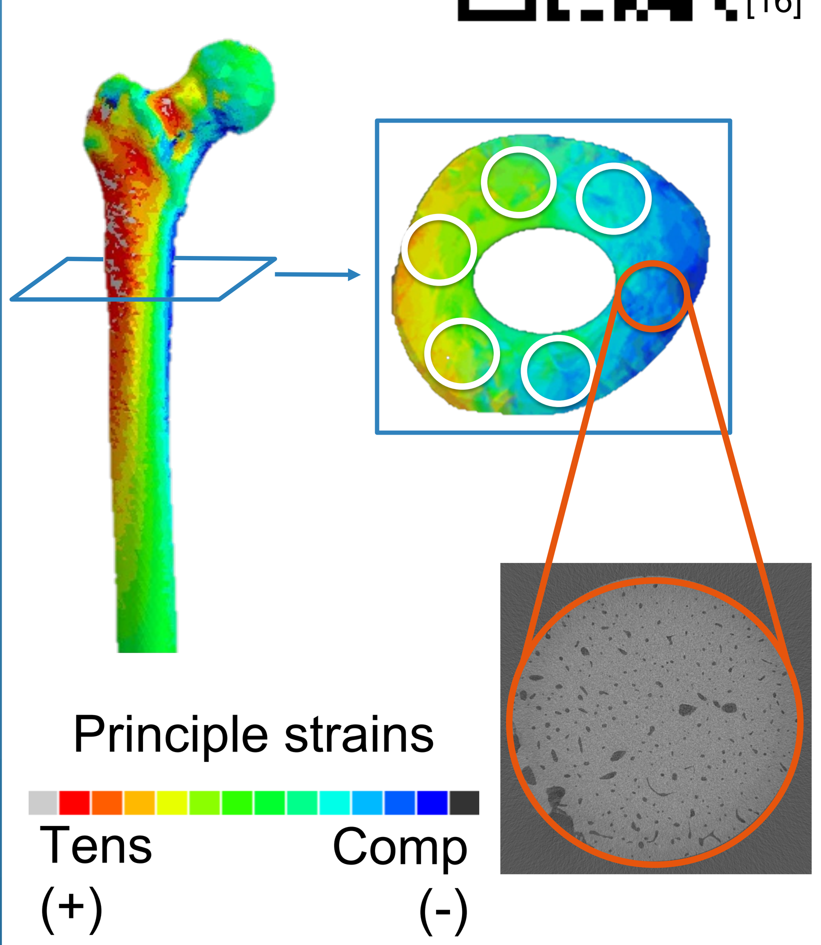
Veins	→	Canals
Branch points	→	Nodes
Leaf areas	→	Cortical bone



3. Characterizing local strain environment

Muscle-driven finite element models:

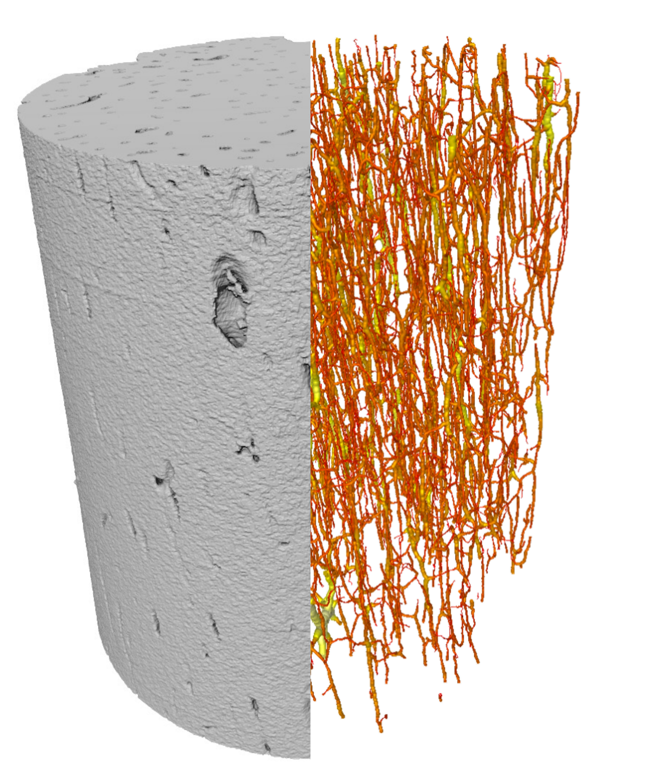
- Mechanical loading of cortical bone during walking[15]



4. Pore morphology measurements

Sample removal and µCT scan:

- Cores (ø=5mm, n=6) and I-beams (t_g=2mm, n=5) were removed from compression and tension regions

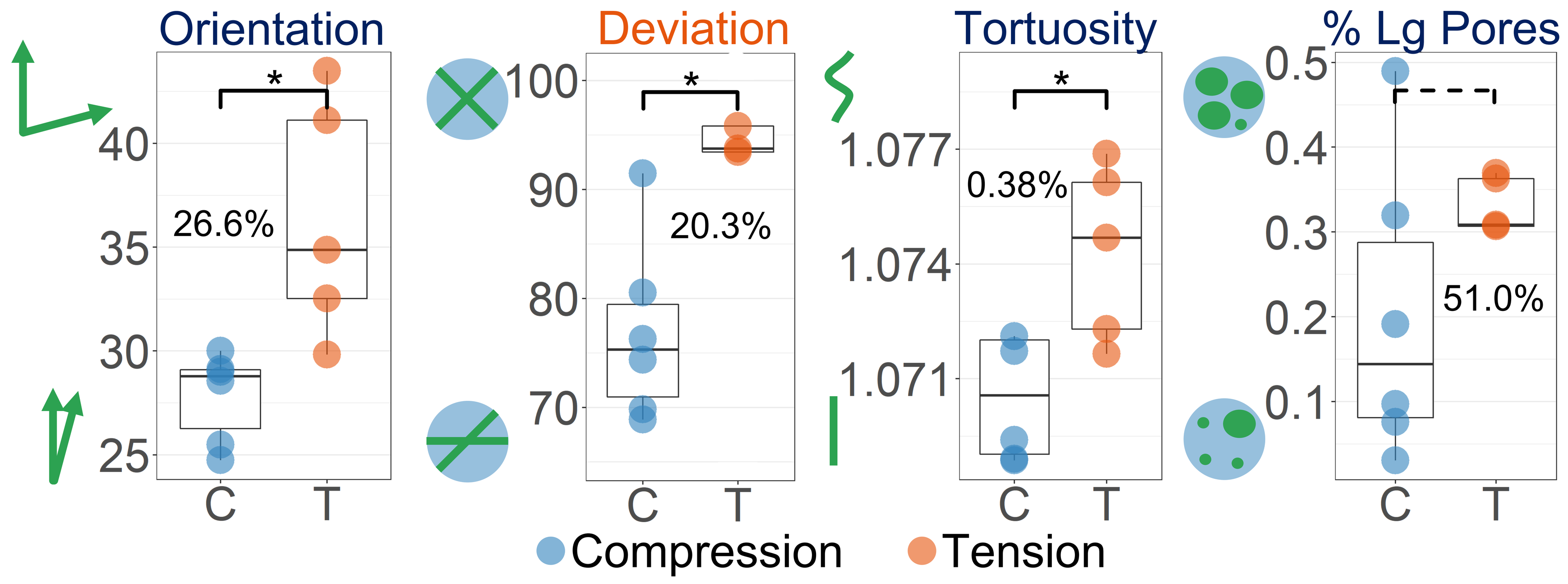


3D pore network:

- µCT scans filtered, binarized, and auto-skeletonized

5. Key findings

- Orientation and rotating angle deviation (a new pore characteristic) were different between compressive and tensile regions



	Pore measures: mean(SD)	Comp	Tens
Classical	Porosity	22.1 (8.4)	25.7 (7.0)
	Median canal length	0.13 (0.03)	0.12 (0.01)
	Canal Density	53.6 (18.0)	51.1 (15.6)
New	Median bifurcation angle	70.8 (3.7)	71.6 (3.0)
	Median haversian canal length	0.16 (0.04)	0.14 (0.02)
	Median Volkmann length	0.1 (0.02)	0.1 (0.01)
	Volkmann canal density	18.2 (5.5)	22.2 (7.9)
	Volkmann: haversian diameter ratio	1.10 (0.04)	1.16 (0.12)

6. Conclusions

- One new measure identified
- Structural changes may be driven by differences in the loading environment
- Bone in compressive regions have canals that are straight and more vertical

- Tensile regions have less organized porosity

Limitations: small sample size (n=6 compression & n=5 tension)

Future work: More samples; investigate sensitivity to (1) location along the diaphysis and (2) strain magnitude; mechanical testing

Acknowledgements

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References

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