Klinikum rechts der Isar
Technische Universität München

Osteoporosis: Imaging-based fracture risk prediction

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Osteoporosis Research Group and Collaborators

Group Leaders:

- Jan Bauer, MD (Department of Neuroradiology)
- Thomas Baum, MD (Department of Radiology)

Collaborators: Klinikum rechts der Isar Technische Universität München

- CT Image Reconstruction Group, Department of Radiology (Peter Noël, PhD)
- MRI Research Group, Department of Radiology (Dimitrios Karampinos, PhD)
- Biomechanical Lab, Department of Orthopedic Surgery (Rainer Burgkart, MD)

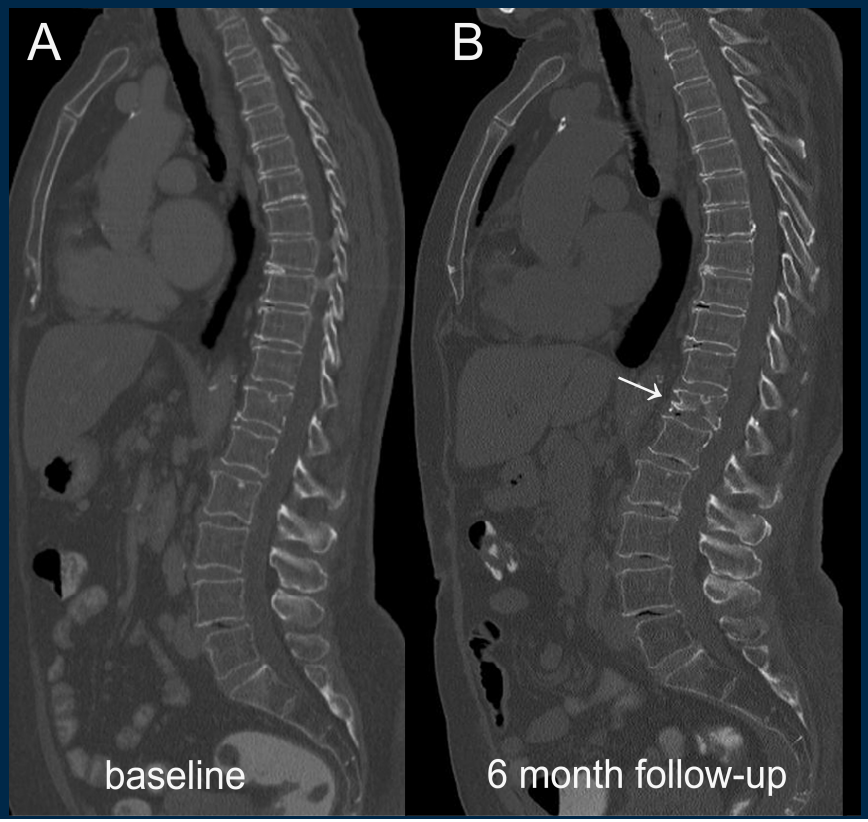
Collaborators:

- Biomedical Physics, E17 (Prof. Franz Pfeiffer, PhD)
- Computation in Engineering (Prof. Ernst Rank, PhD)
- MPE (Christoph Räth, PhD)
- MQIR Group, UCSF (Prof. Thomas Link, MD)

Funding Sources: DFG Deutsche Forschungsgemeinschaft

Osteoporosis

is defined as a skeletal disorder characterized by compromised bone strength predisposing an individual to an increased risk of fracture.



Economic Burden of Osteoporotic Fractures

Germany:

The health burden and costs of osteoporotic fractures from 2010 to 2050 are estimated up to 88.5 billion Euros.

→ increased morbidity and mortality

Bleibler et al. Osteoporosis International 2013

Clinical Goal

- To identify patients with osteoporotic fractures
- To identify patients at high risk of osteoporotic fractures

to initiate appropriate therapy.

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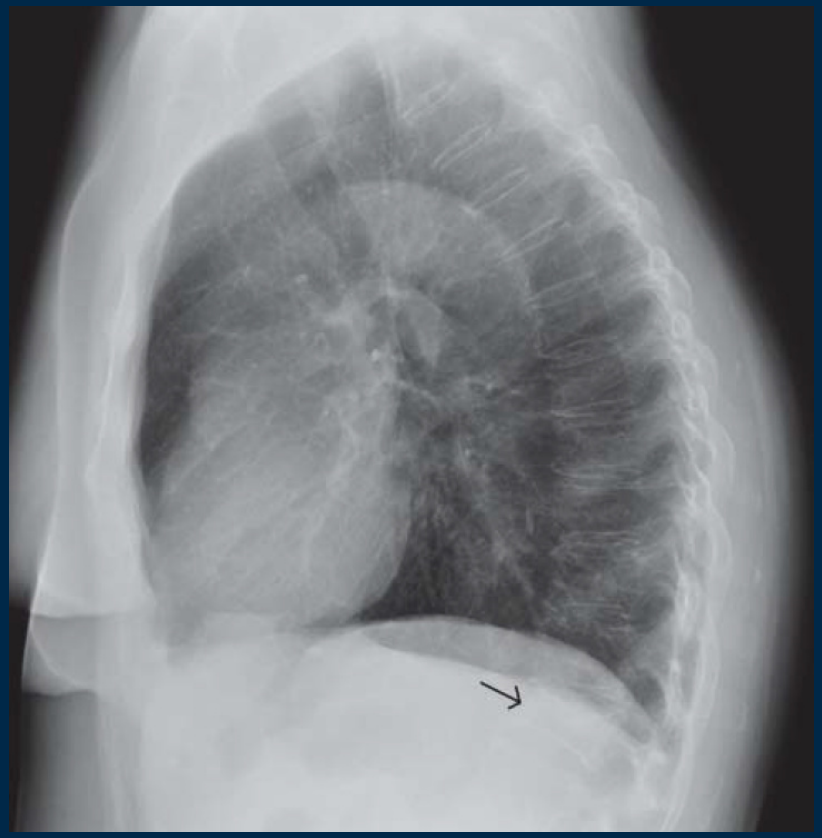
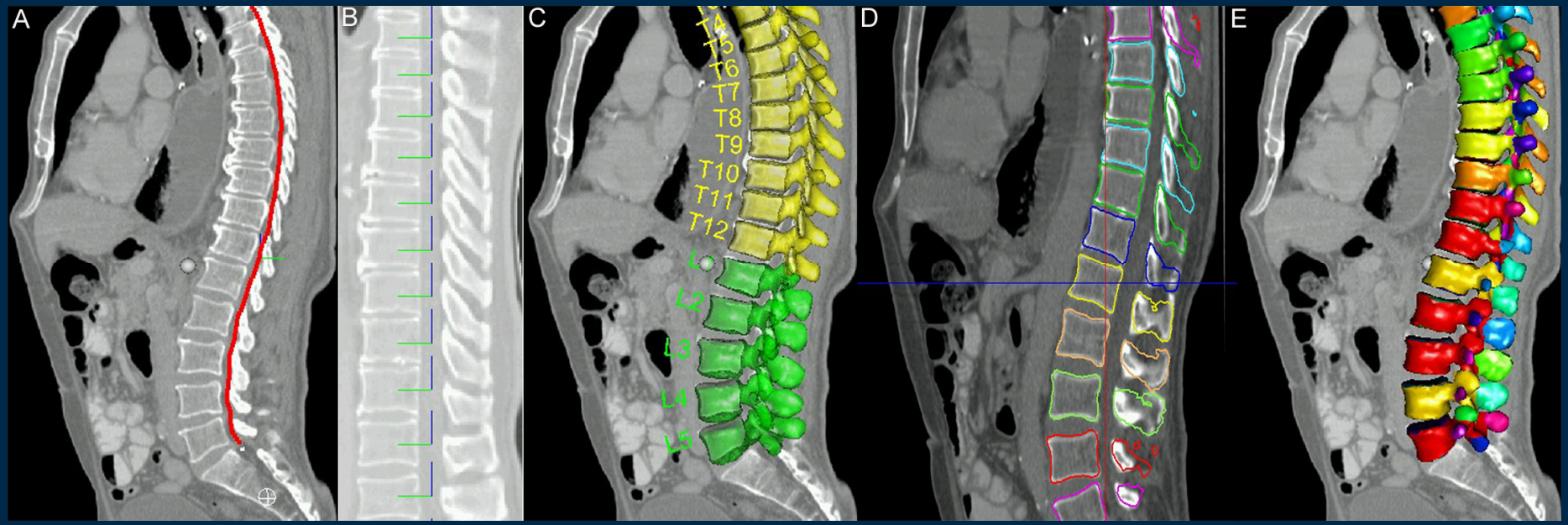
Diagnosis of Osteoporotic Vertebral Fractures

→ underreported by radiologists in routine exams



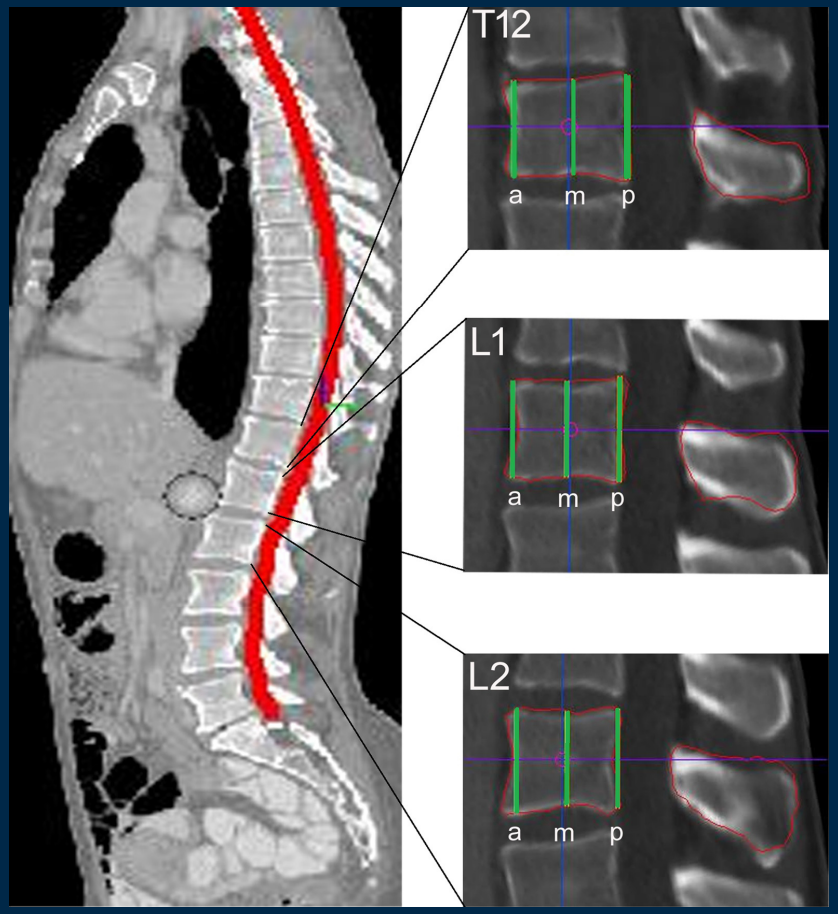
Automatic Detection of Osteoporotic Fractures

Automatic detection, identification, and segmentation of the vertebrae in MDCT images:



Baum et al. European Radiology 2014

Automatic Detection of Osteoporotic Fractures



Baum et al. European Radiology 2014

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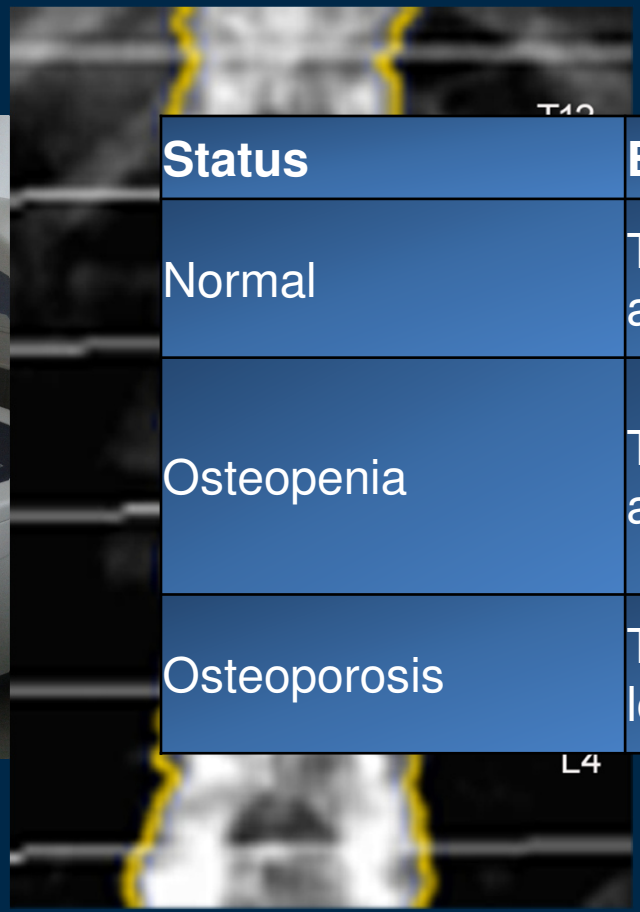
Prediction of Bone Strength

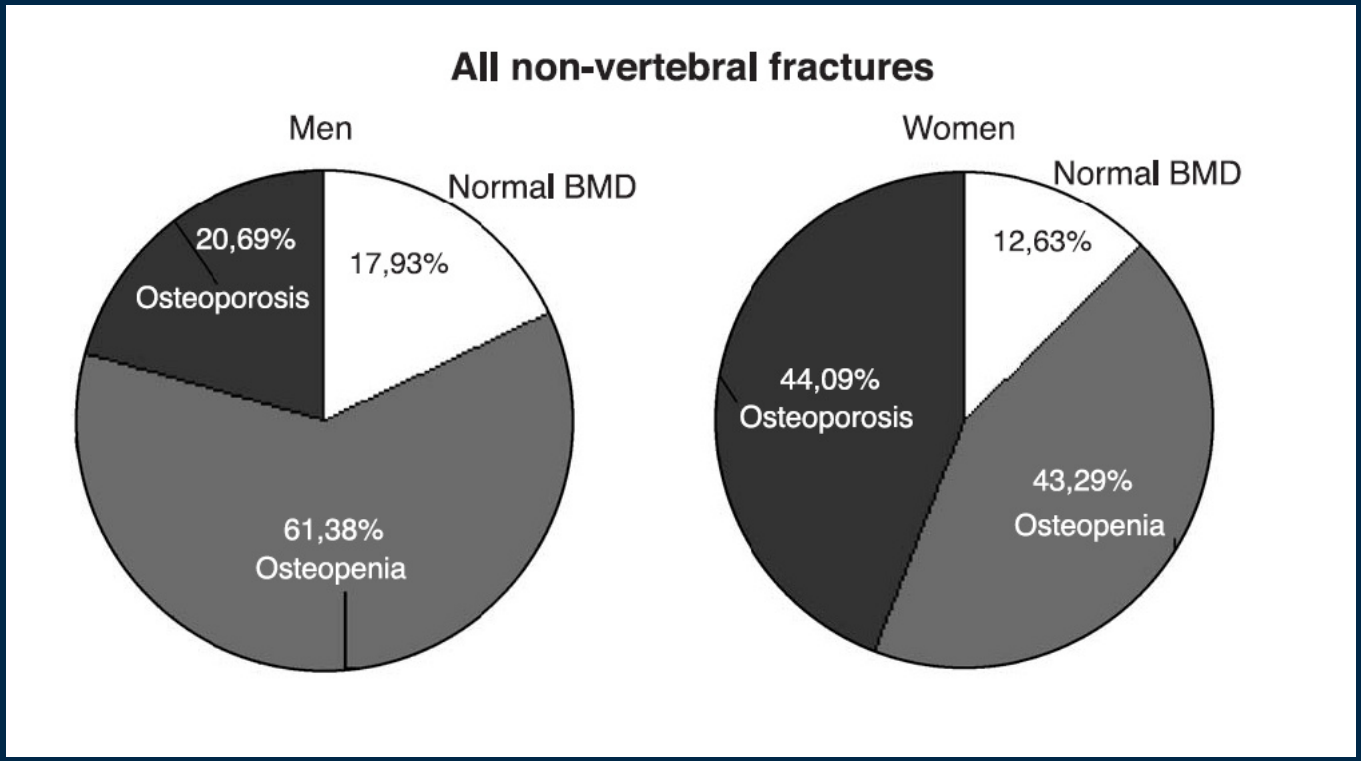
Based on BMD measurements at the spine/hip using DXA



Status	BMD
Normal	T-score of -1 or above
Osteopenia	T-score lower than -1 and greater than -2.5
Osteoporosis	T-score of -2.5 or lower

Prediction of Bone Strength

T-scores and BMD values of patients with and without osteoporotic fractures overlap:



Schuit et al. Bone 2004

Prediction of Bone Strength beyond BMD

Bone strength primarily reflects the integration of BMD and bone quality.

Bone quality includes:

- Bone microstructure
- Bone composition

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High-Resolution Bone Imaging

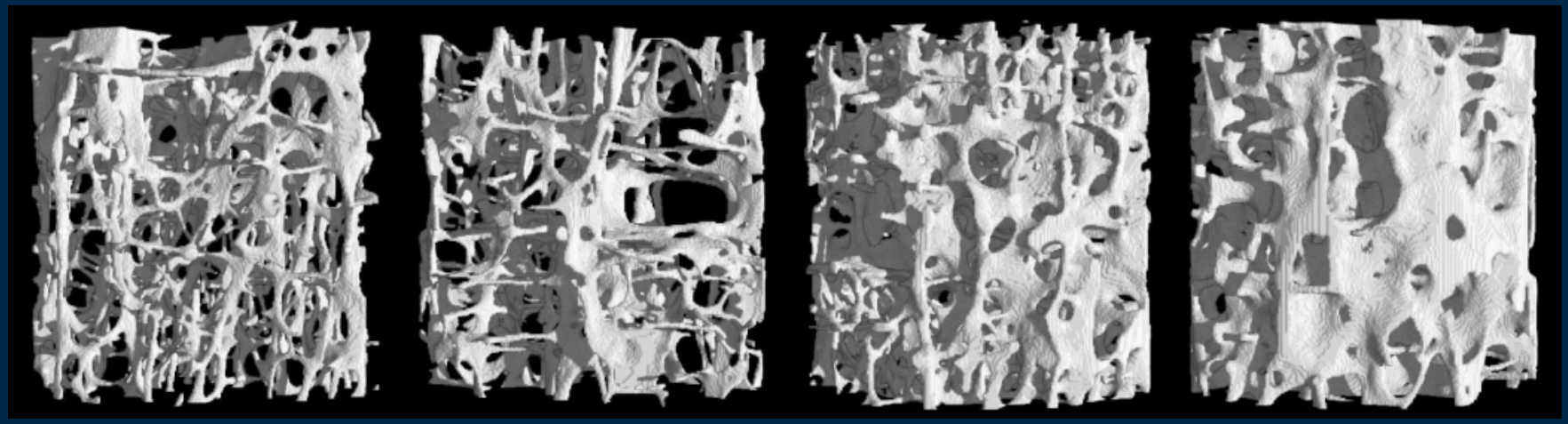
Technical considerations:

- Trabeculae have a diameter between 50 and 200 µm.
- Cortical thickness varies between 0.2 to 5 mm.

High-Resolution Bone Imaging

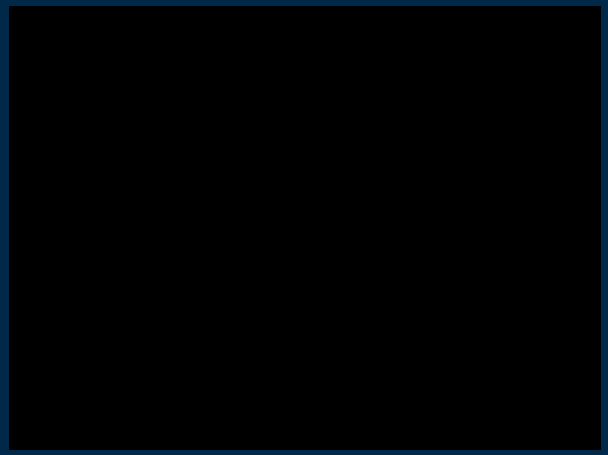
Micro Computed Tomography (µCT):

- spatial resolution up to 8 μm^3
- ex-vivo

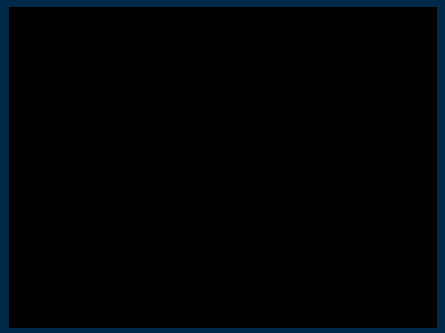


High-Resolution Bone Imaging

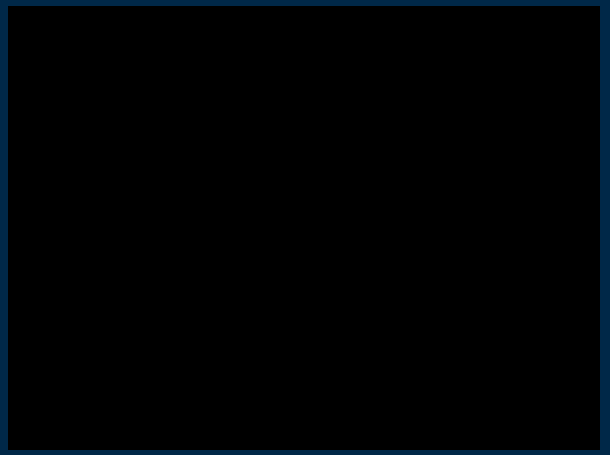
Trabecular bone microstructure analysis:



normal bone sample



galaxy



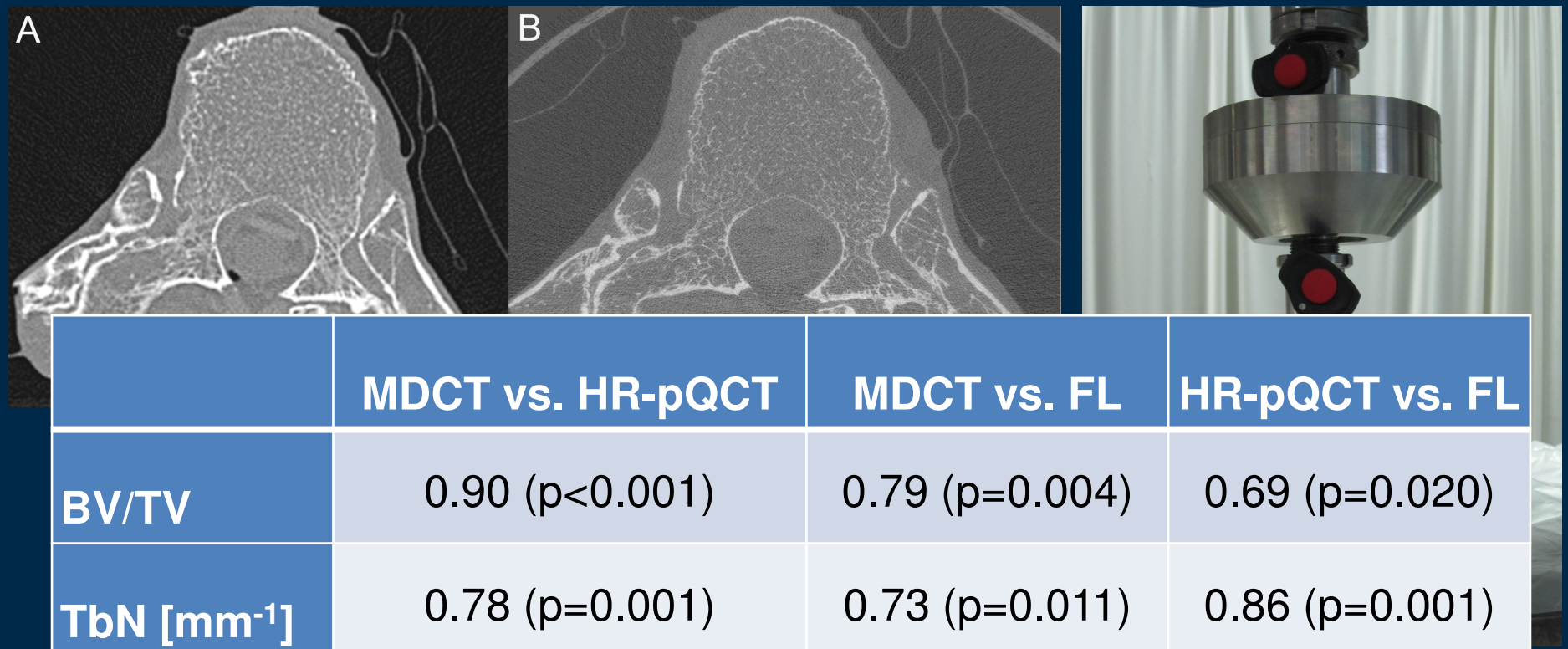
osteoporotic bone sample

Räth et al. Bone 2013

Clinical MDCT and MRI

→ have not sufficient spatial resolution to reveal the true bone microstructure

Clinical MDCT versus HR-pQCT

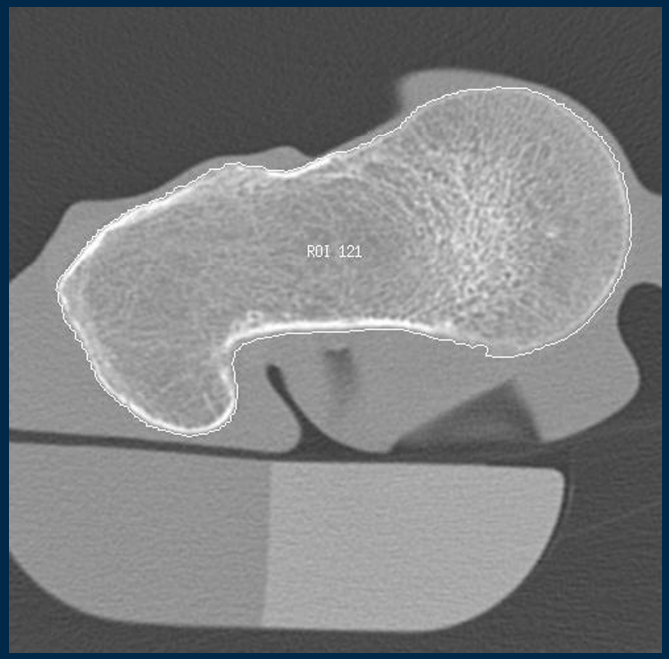


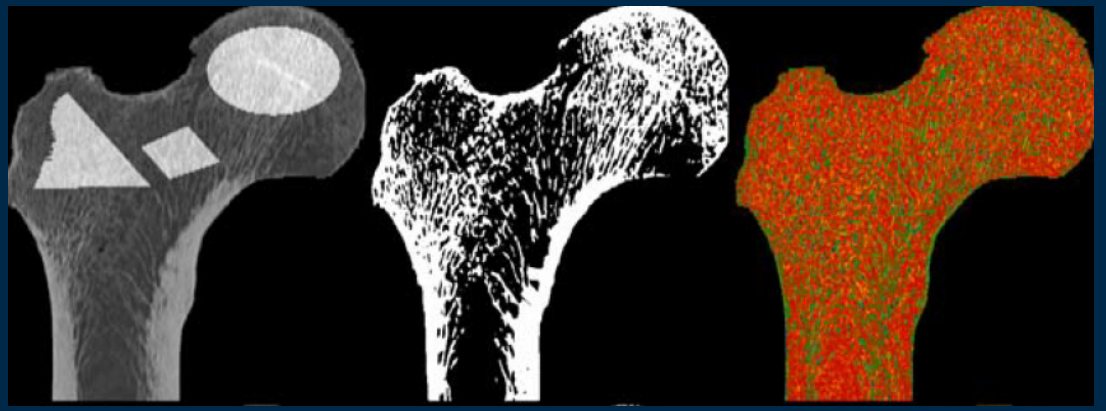
	MDCT vs. HR-pQCT	MDCT vs. FL	HR-pQCT vs. FL
BV/TV	0.90 (p<0.001)	0.79 (p=0.004)	0.69 (p=0.020)
TbN [mm^{-1}]	0.78 (p=0.001)	0.73 (p=0.011)	0.86 (p=0.001)
FD	0.60 (p=0.038)	0.69 (p=0.018)	0.85 (p=0.003)

Baum et al. Journal of Bone and Mineral Metabolism 2014

Prediction of Bone Strength beyond BMD

Trabecular bone microstructure analysis:



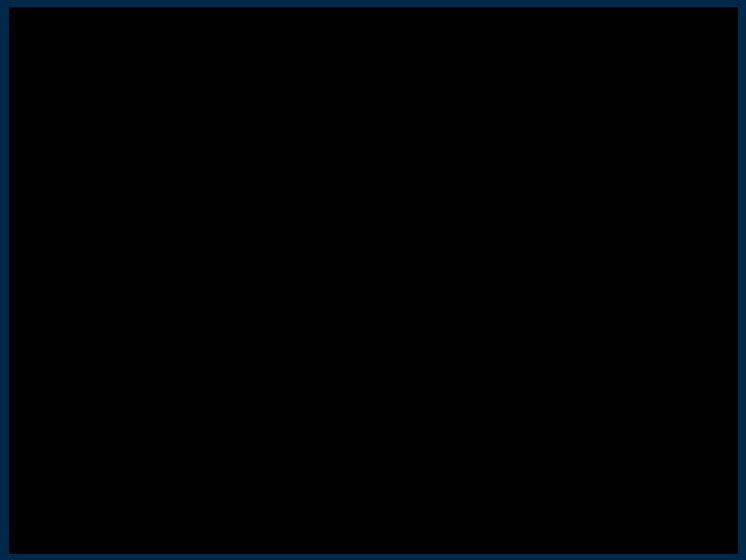


→ allowed for a significant better prediction than DXA-BMD alone: up to R(adj)=0.87

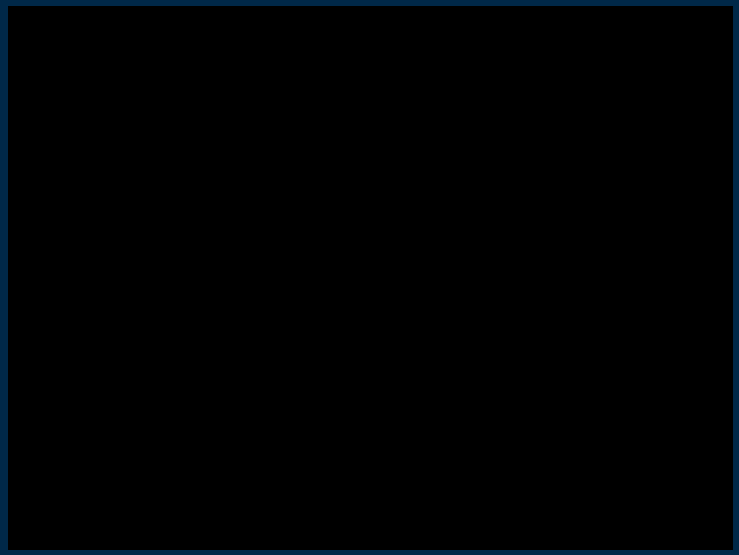
Baum et al. Osteoporosis International 2010

Prediction of Bone Strength beyond BMD

Trabecular bone microstructure analysis:



normal

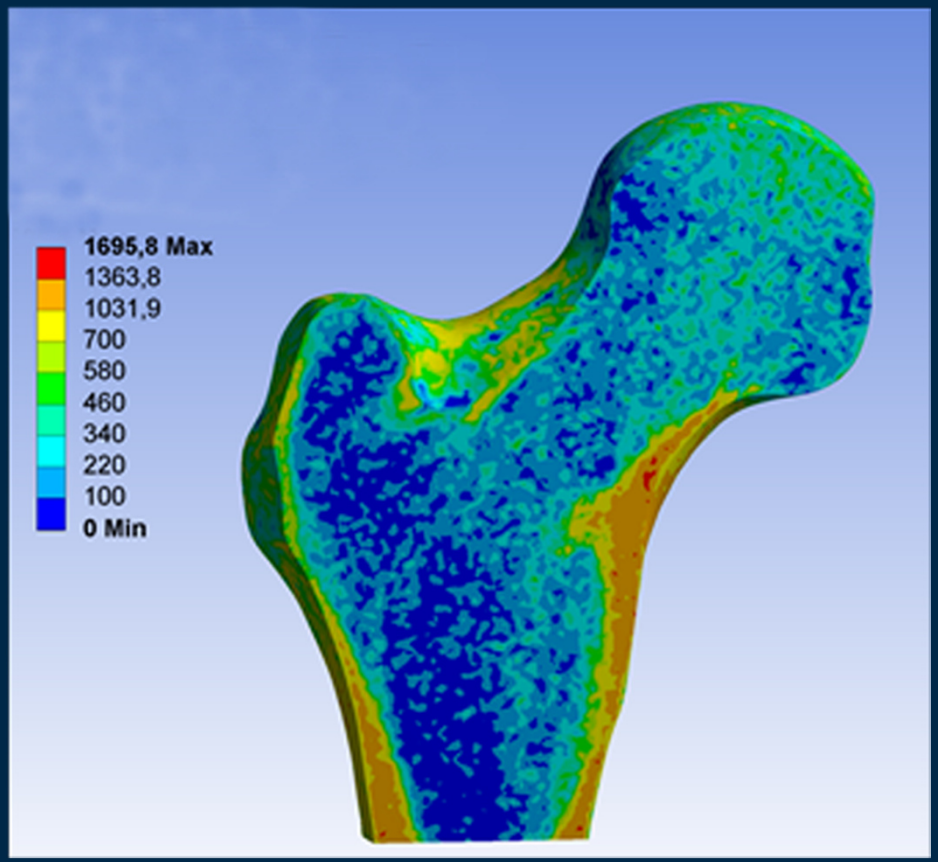


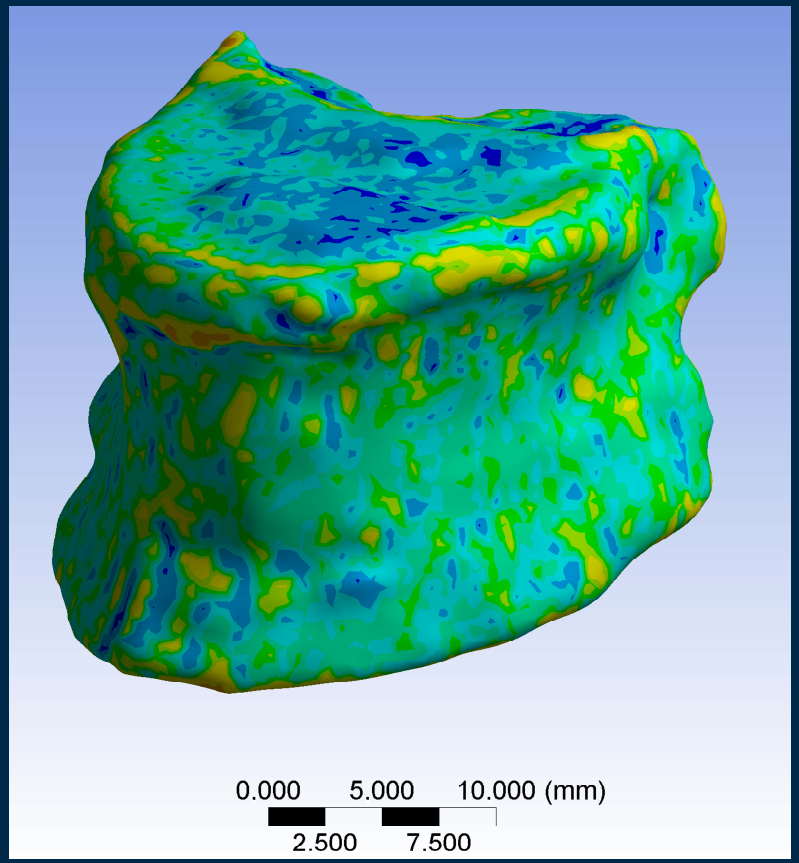
osteoporotic

Baum et al. Journal of Bone and Mineral Metabolism 2013

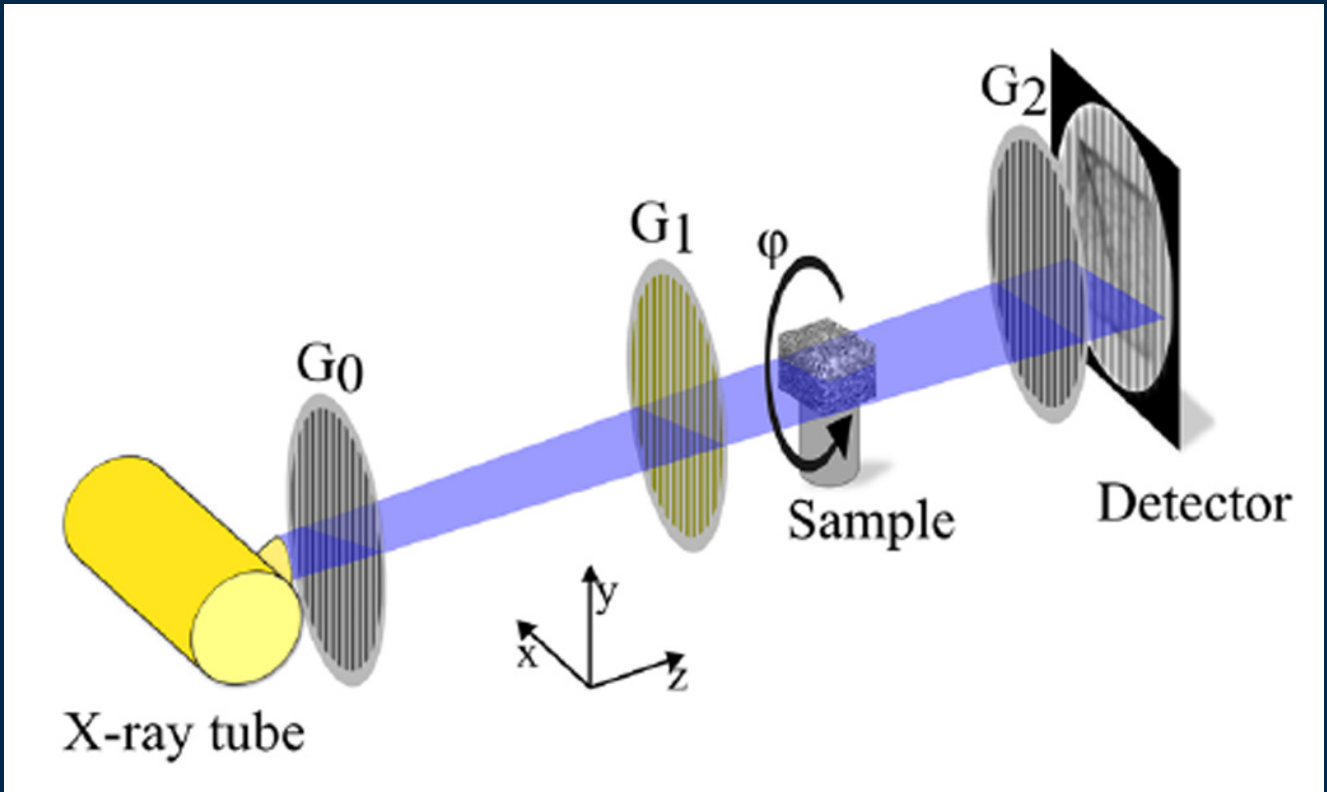
Prediction of Bone Strength beyond BMD

Finite Element Models:



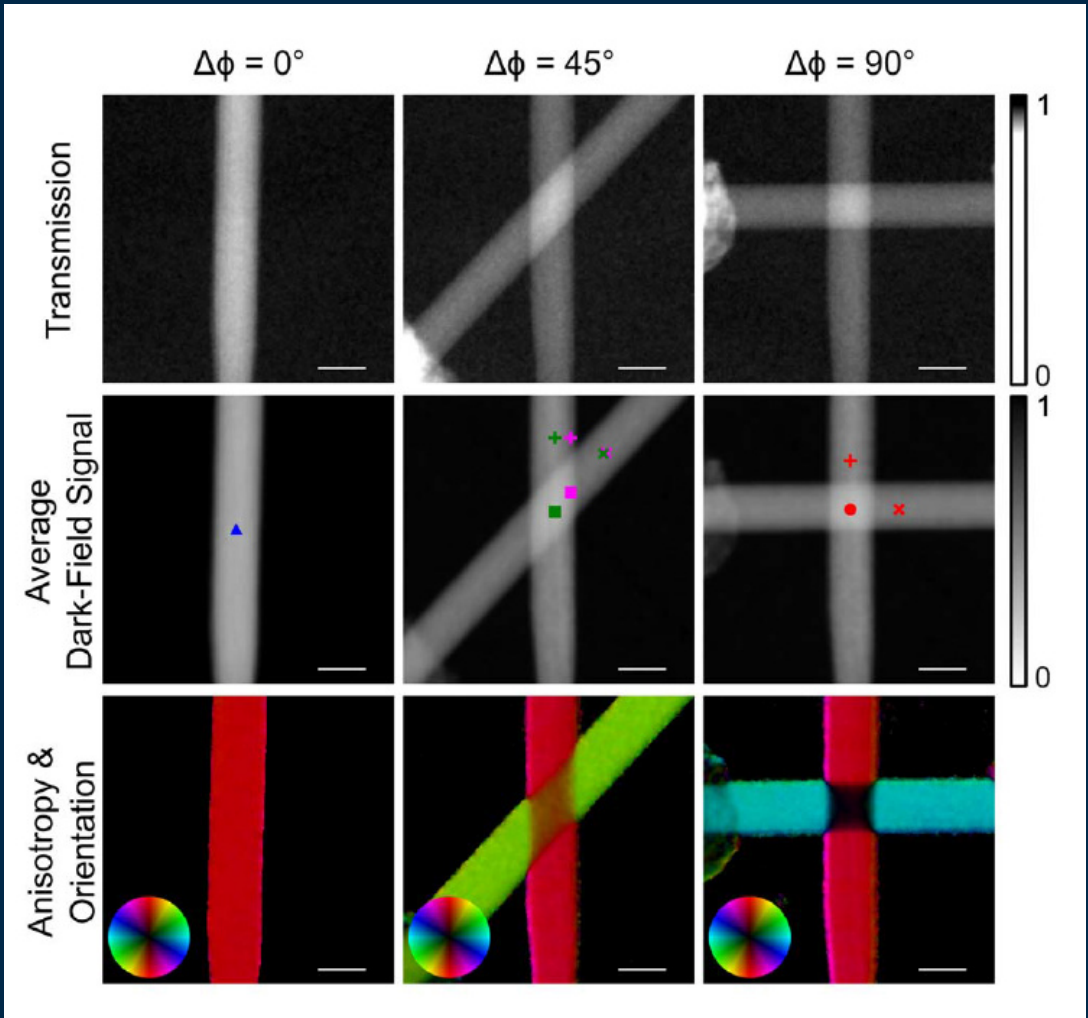


X-ray Dark-Field Vector Radiography (XVR)



Pfeiffer et al. Nature Materials 2008, Schaff et al. Nature Scientific Reports 2014

XVR: Prediction of Bone Strength



Malecki et al. Plos One 2013

XVR: Prediction of Bone Strength

Baum et al. under review

Prediction of Bone Strength beyond BMD

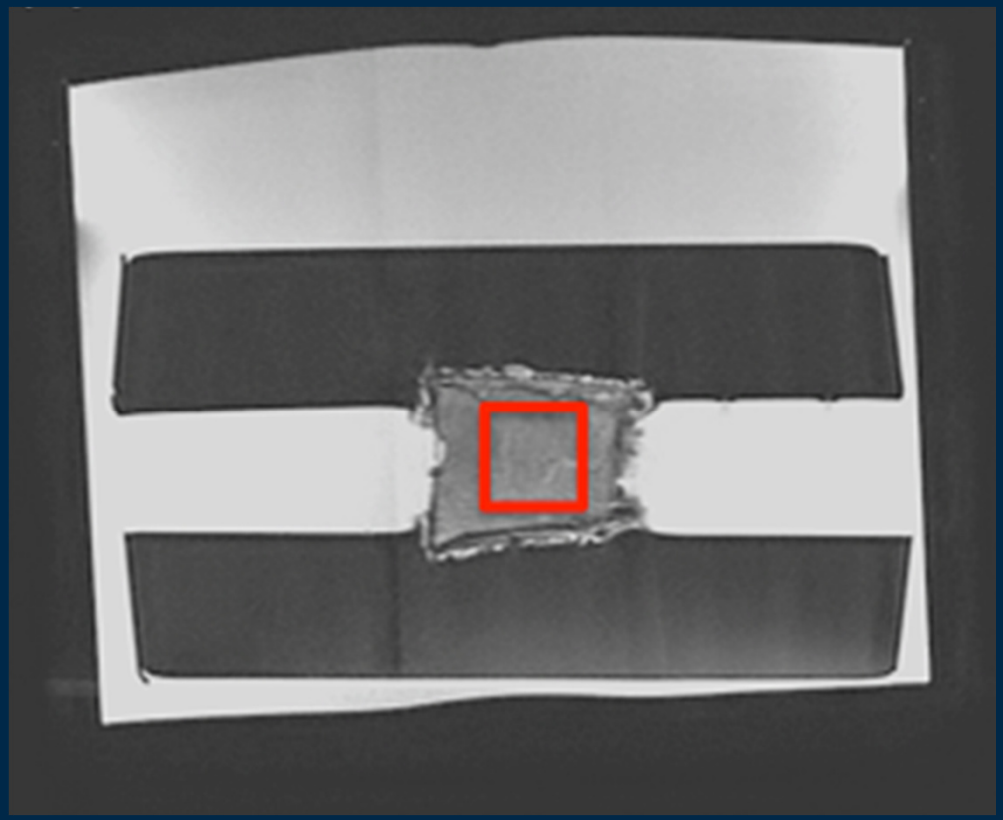
Bone strength primarily reflects the integration of BMD and bone quality.

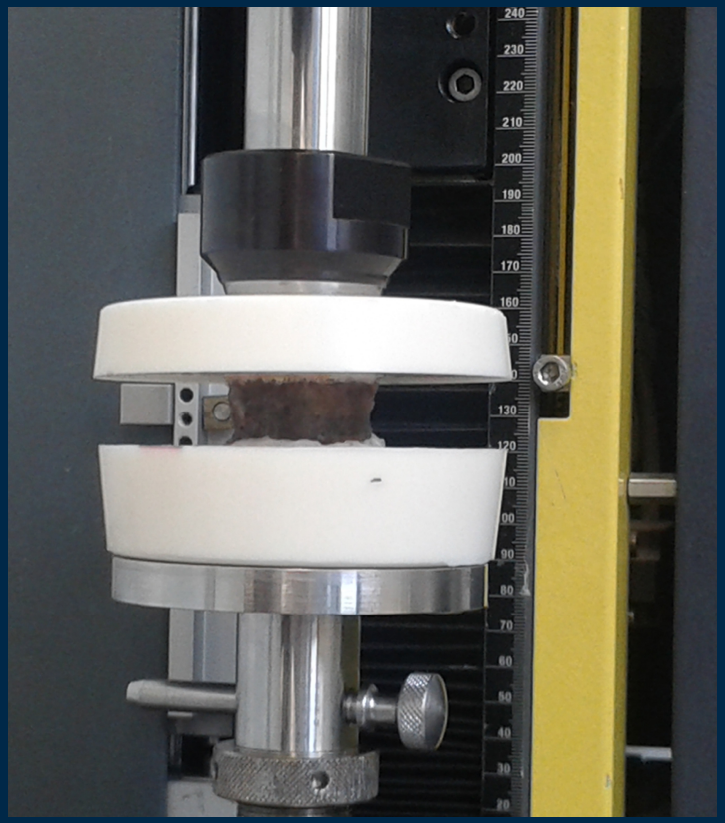
Bone quality includes:

- Bone microstructure
- Bone composition

Bone Composition assessed by MRS

Bone marrow fat content:





Karampinos et al. under review

MRS: Prediction of Bone Strength

Bone marrow fat content:

Karampinos et al. under review

Imaging-based fracture risk prediction

- Automatic detection of osteoporotic fractures
- High-resolution bone imaging:

Microarchitecture assessed by MDCT, MRI and XVR

- Imaging of bone composition:

Bone marrow fat content assessed by MRS

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Thanks for your attention.

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