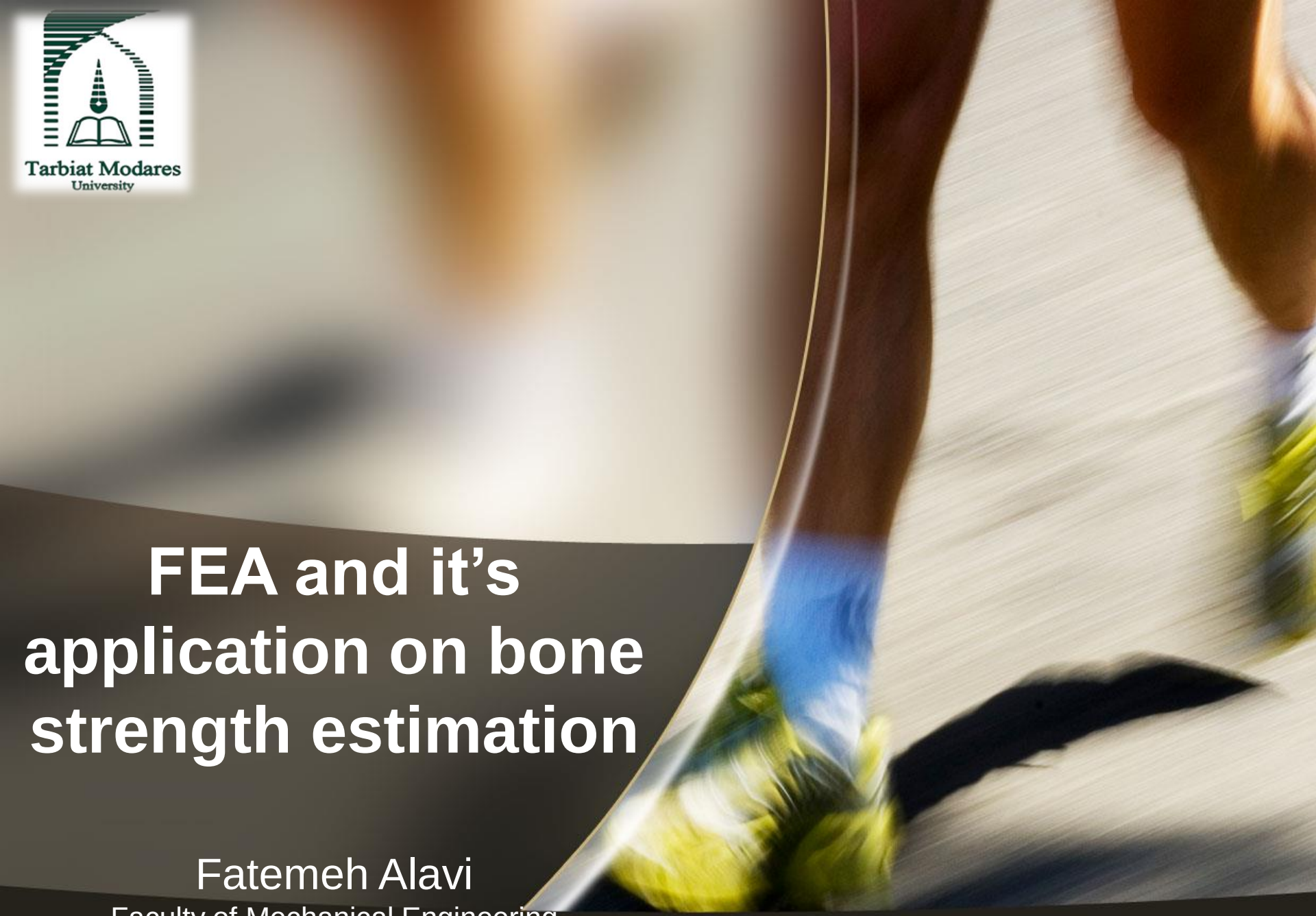
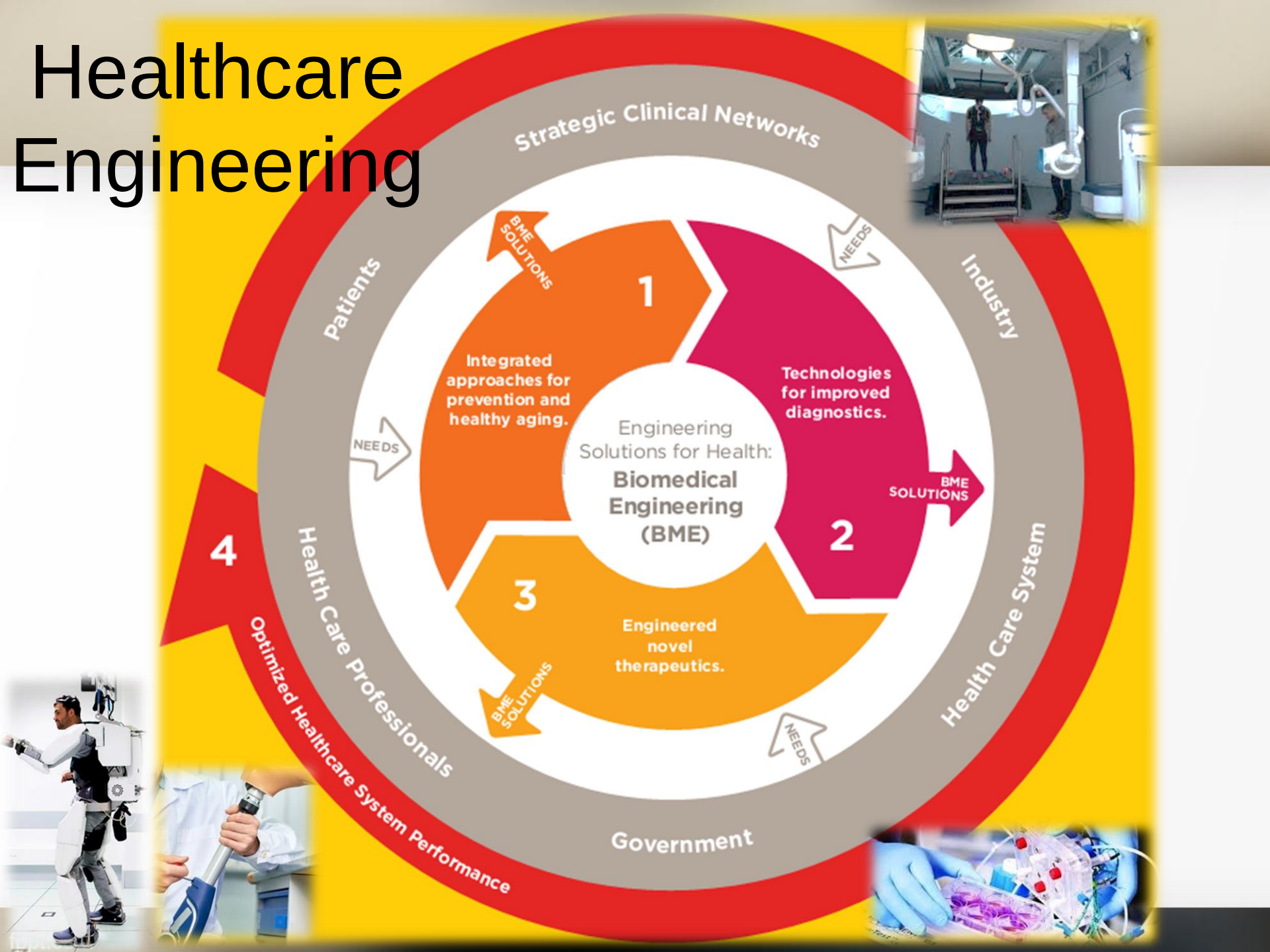


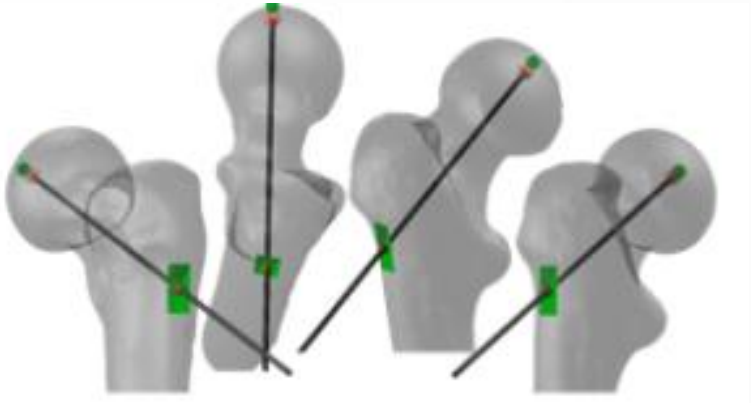
FEA and it’s application on bone strength estimation

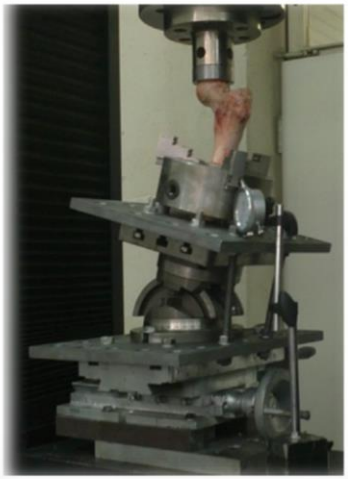
Fatemeh Alavi
Faculty of Mechanical Engineering

Healthcare Engineering

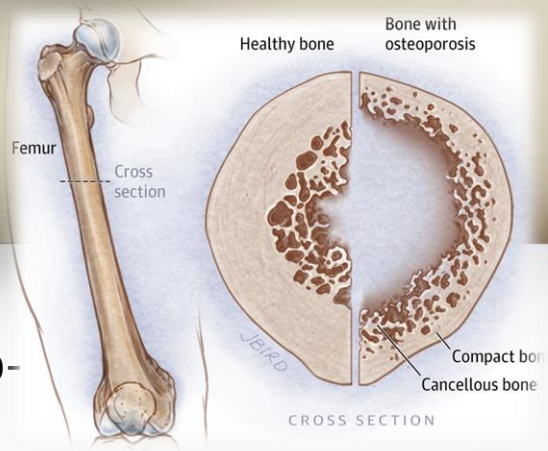


Orthopaedic Biomechanics





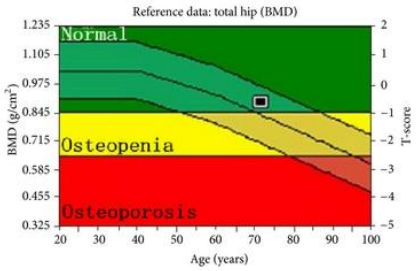
Osteoporosis



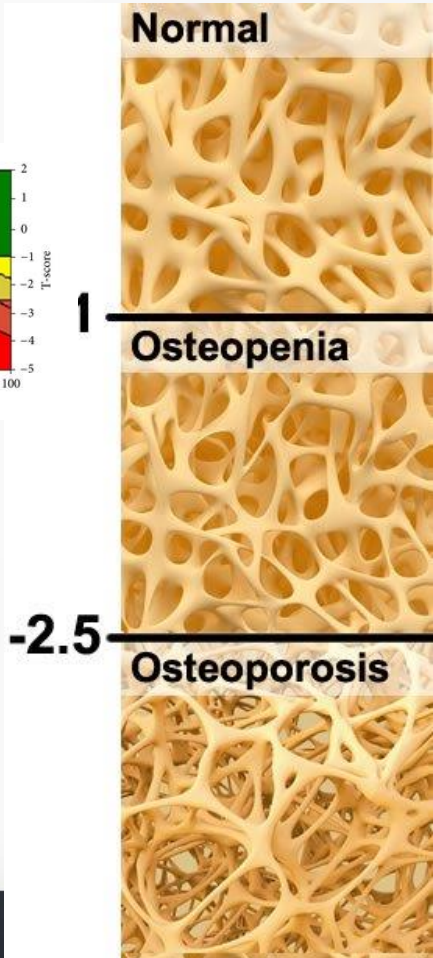
- Osteoporosis is a condition that weakens bones, making them fragile and more likely to break and deteriorate micro-architecture, particularly involves the hip, spine, and wrist.

The diagnosis of osteoporosis can be made using

- conventional radiography
- dual-energy X-ray absorptiometry (DXA) measuring BMD
- QCT
- HR-pQCT



- It develops slowly over several years and is often only diagnosed when a minor fall or sudden impact causes a bone fracture.
- In order to assess osteoporosis one needs parameters quantifying
  - bone mass
  - bone micro-architecture and
  - bone fragility

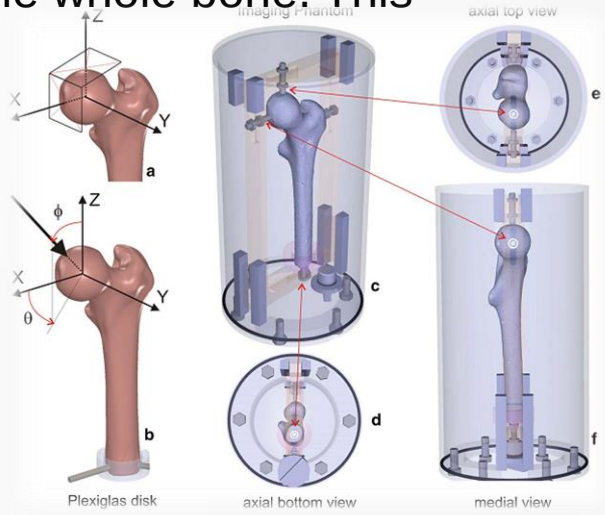


About our research

The diagnosis of osteoporosis involves the assessment of mechanical and structural properties.

To understand the complex relationships between failure of bone tissue and fracture of the whole bone requires a critical analytical step involving calculation of the internal stresses (force intensities) in the whole bone. This step in turn requires knowledge of

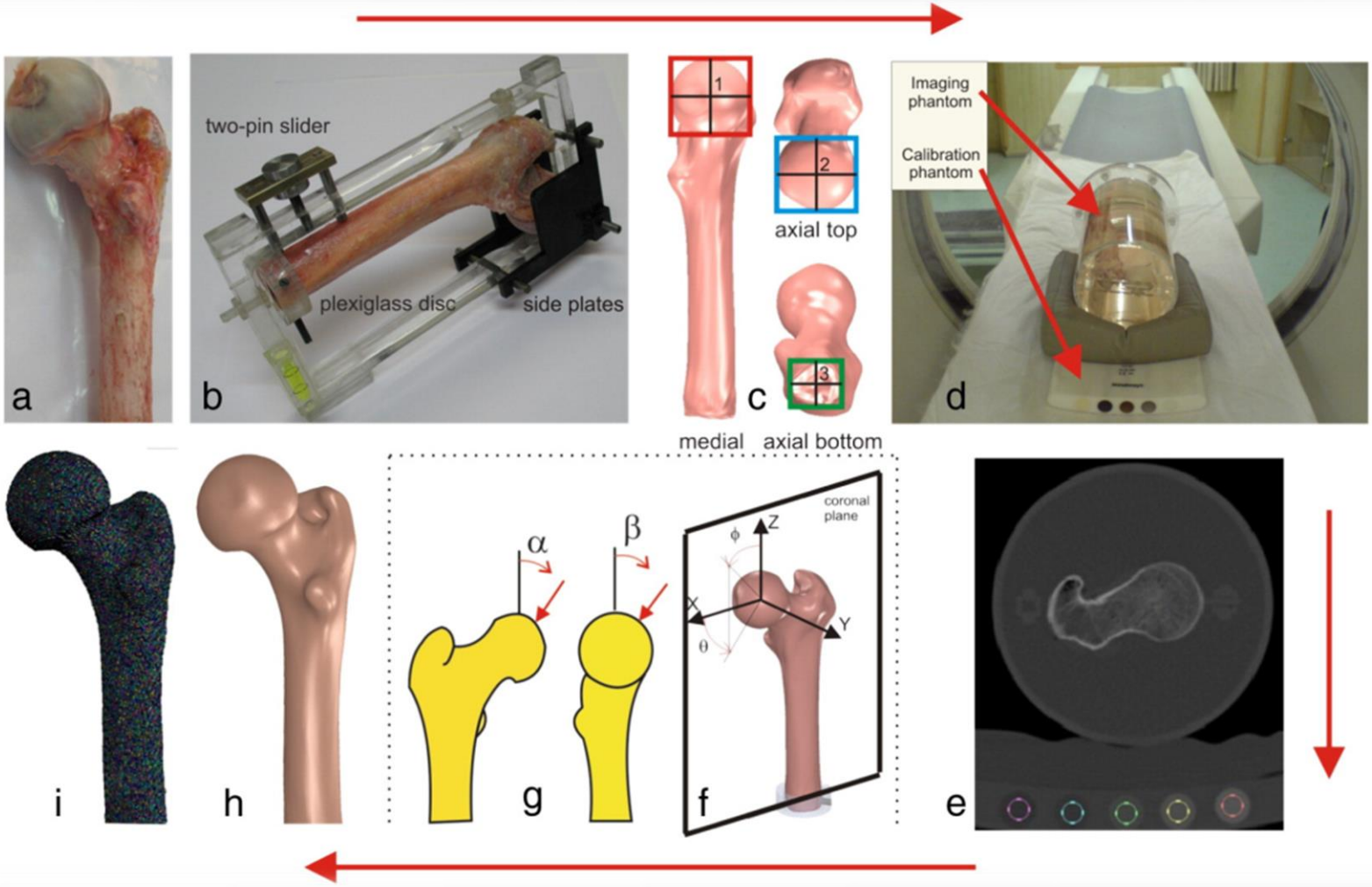
- the geometric features of the whole bone,
- the loads being applied, and
- the material properties of the involved tissues.



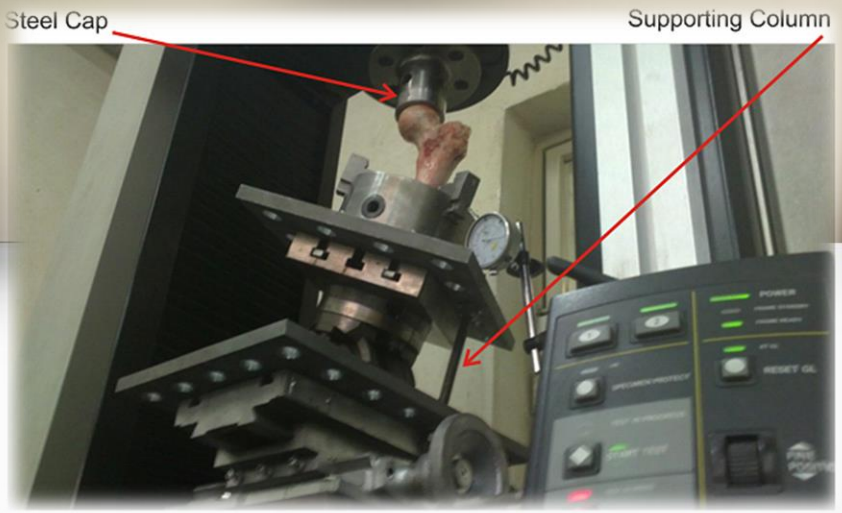
Overview of Procedure

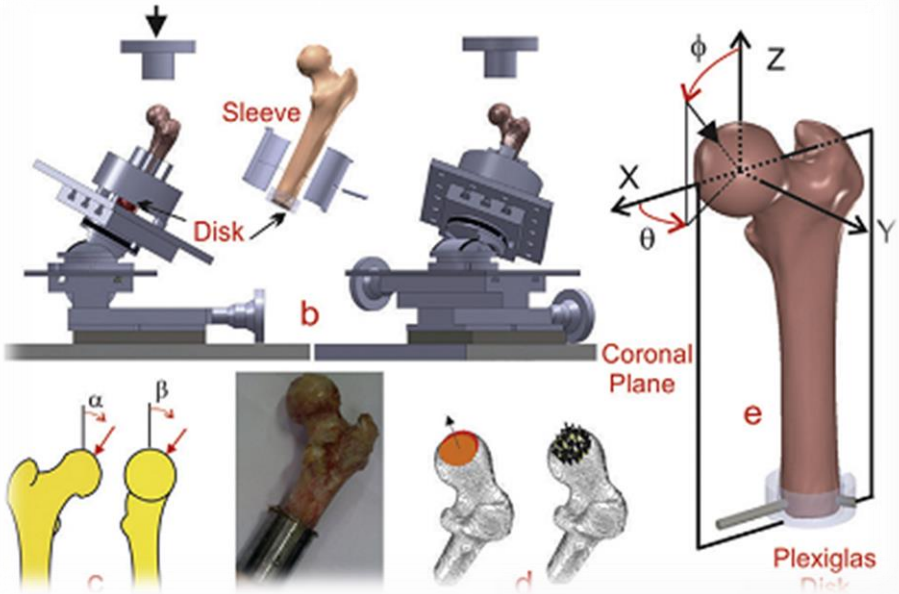
- Sample preparation
- Definition and implementation of the femoral reference system
- QCT scanning
  - Mechanical testing of the proximal femur
  - Finite element analysis

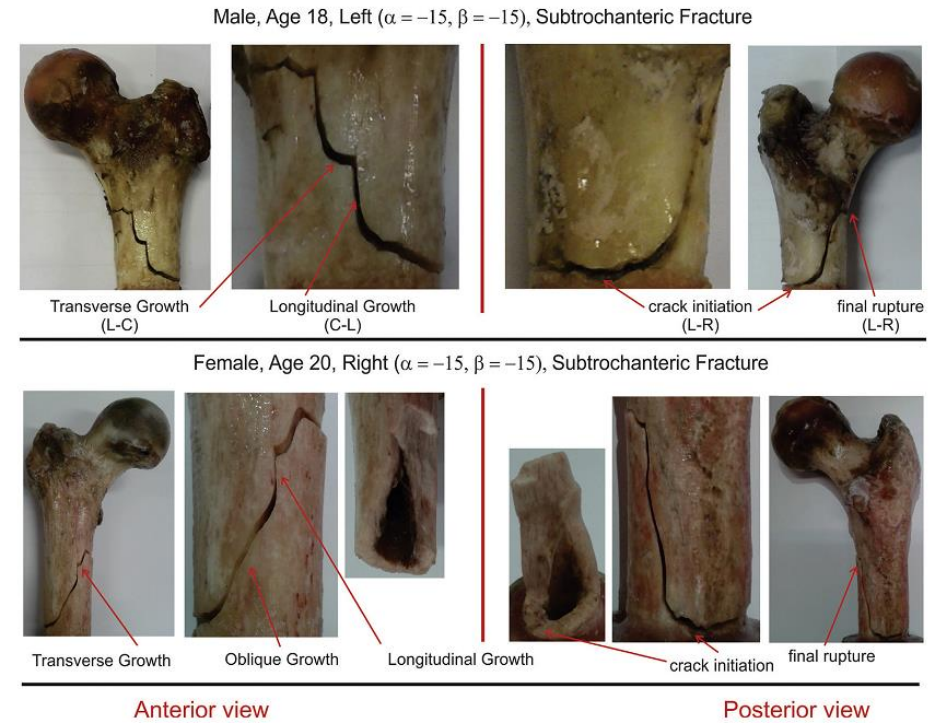
Imaging and creating FE model



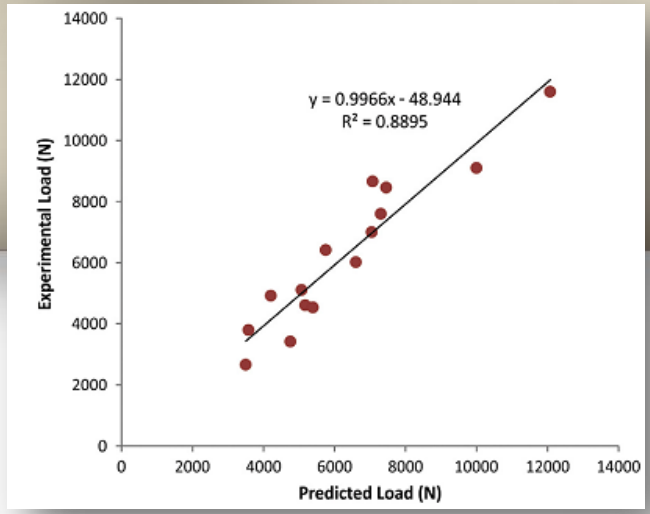
Mechanical Testing

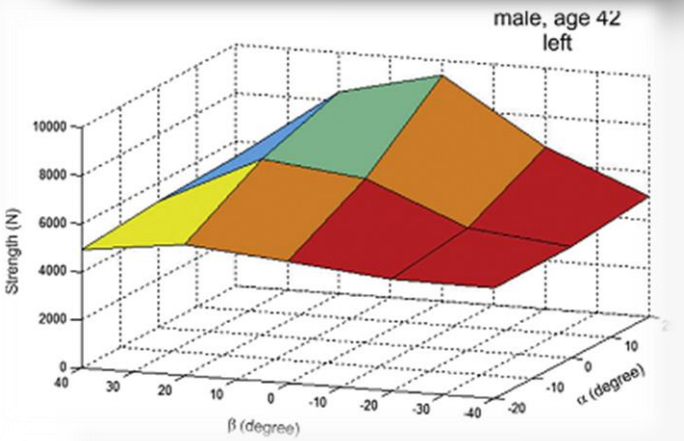


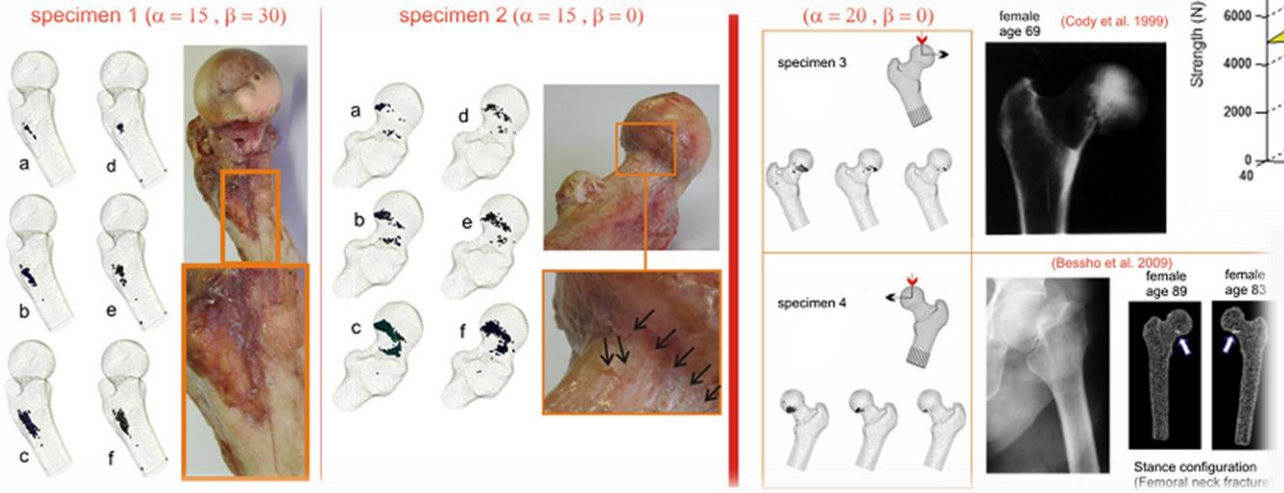




Prediction of strength in different orientation

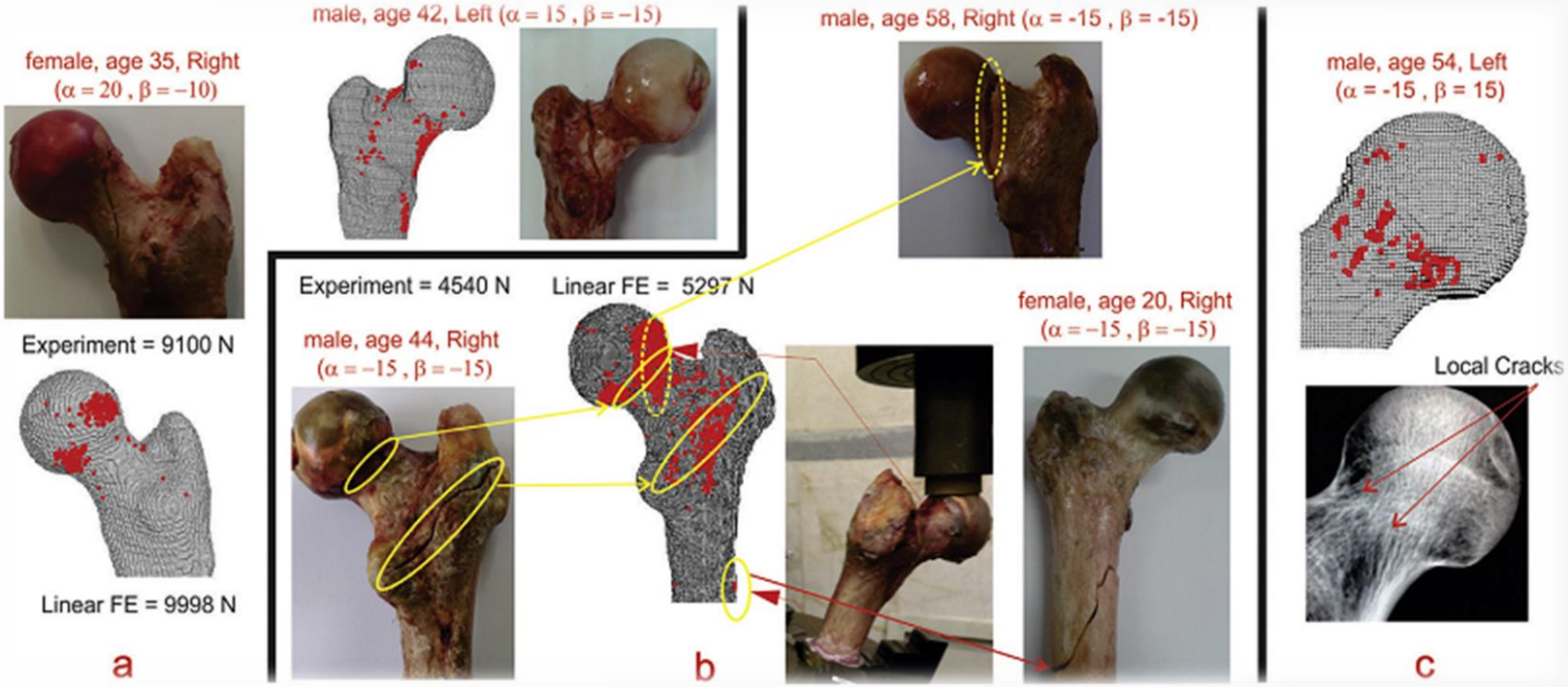






M.Mirzaei, M.Keshavarzian, F. Alavi, P.Amiri, S.Samizadeh, QCT-based failure analysis of proximal femurs under various loading orientation, *Journal of Medical & Biological Engineering & Computing*, 2015, 53(6):477-86.

Prediction of femoral fracture pattern under various loading orientations



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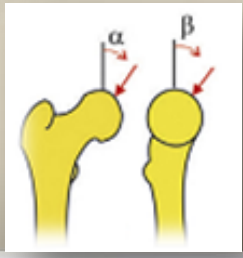
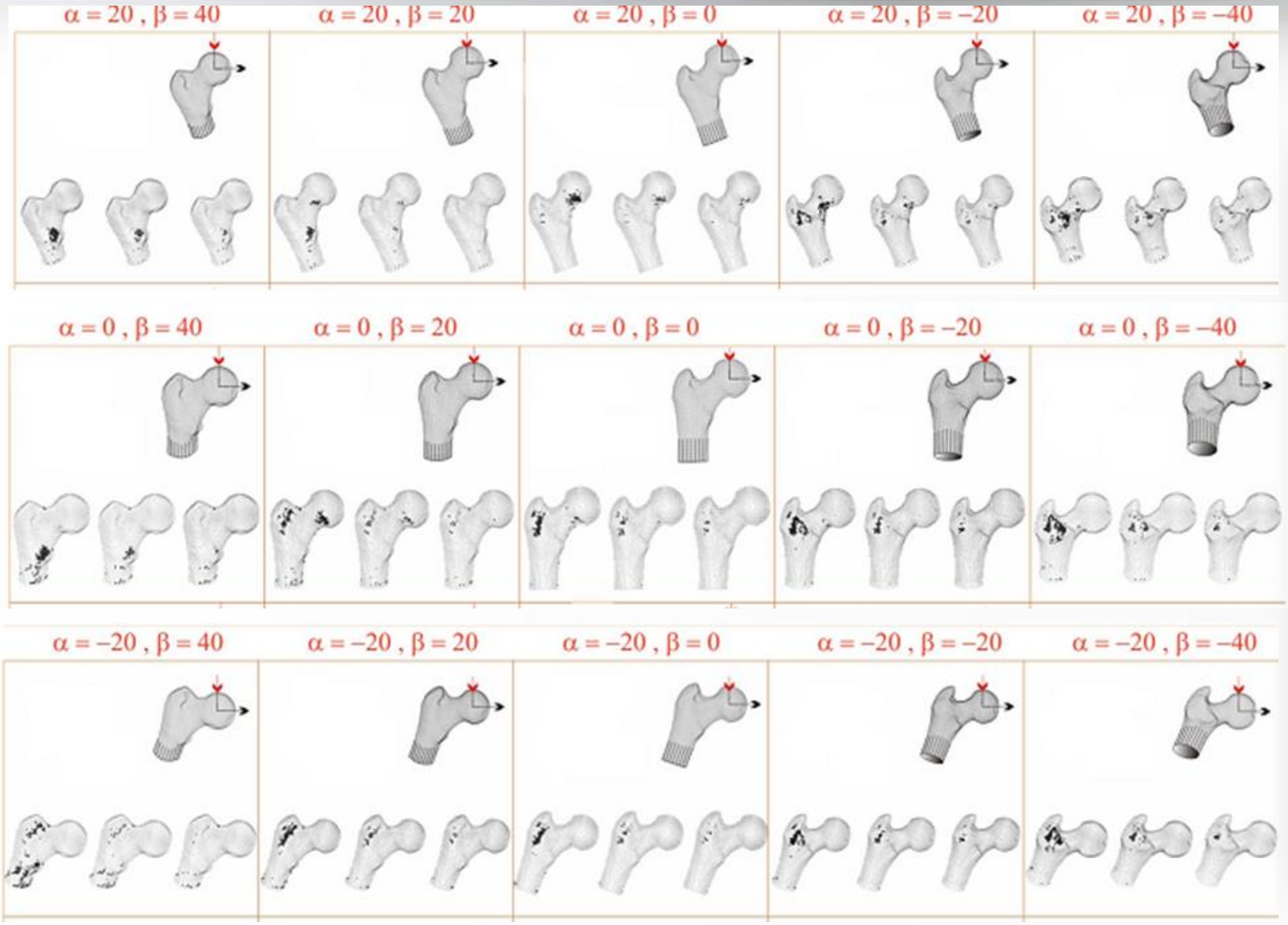
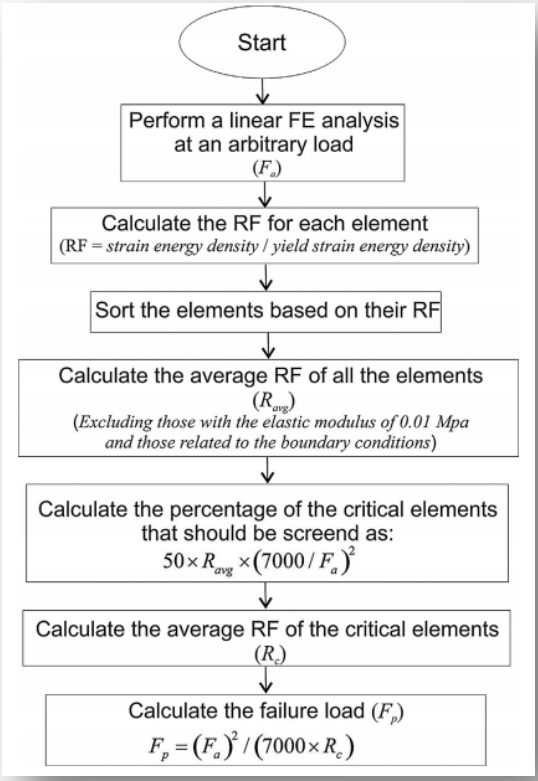
Failure analysis of femurs under various loading orientations

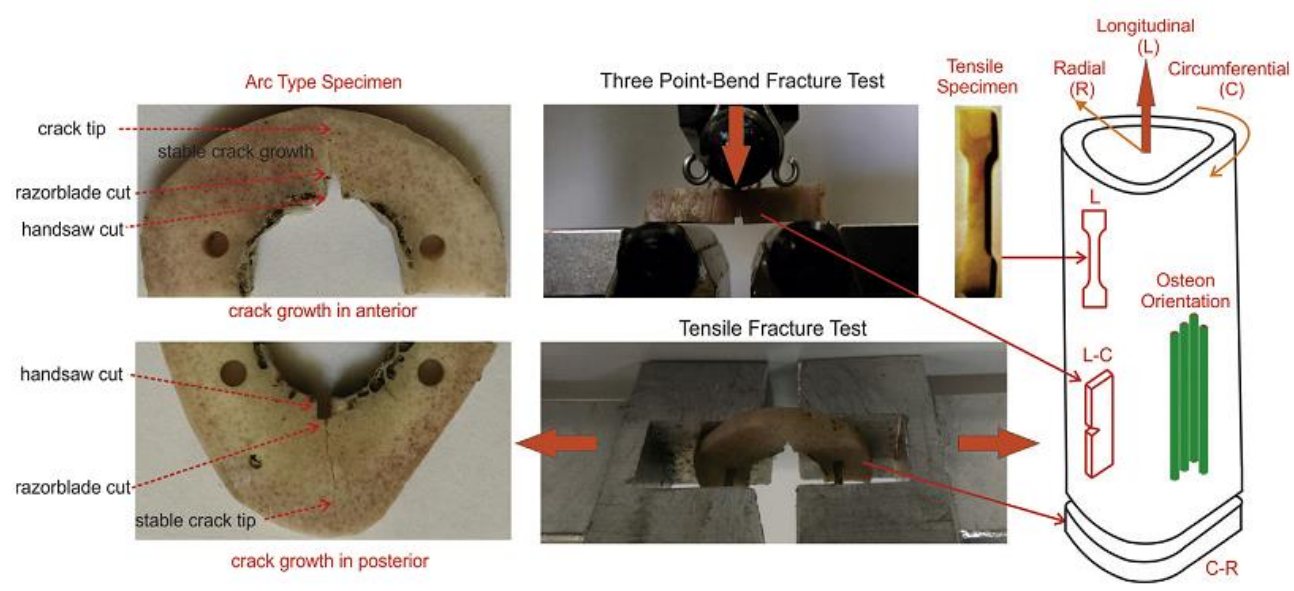




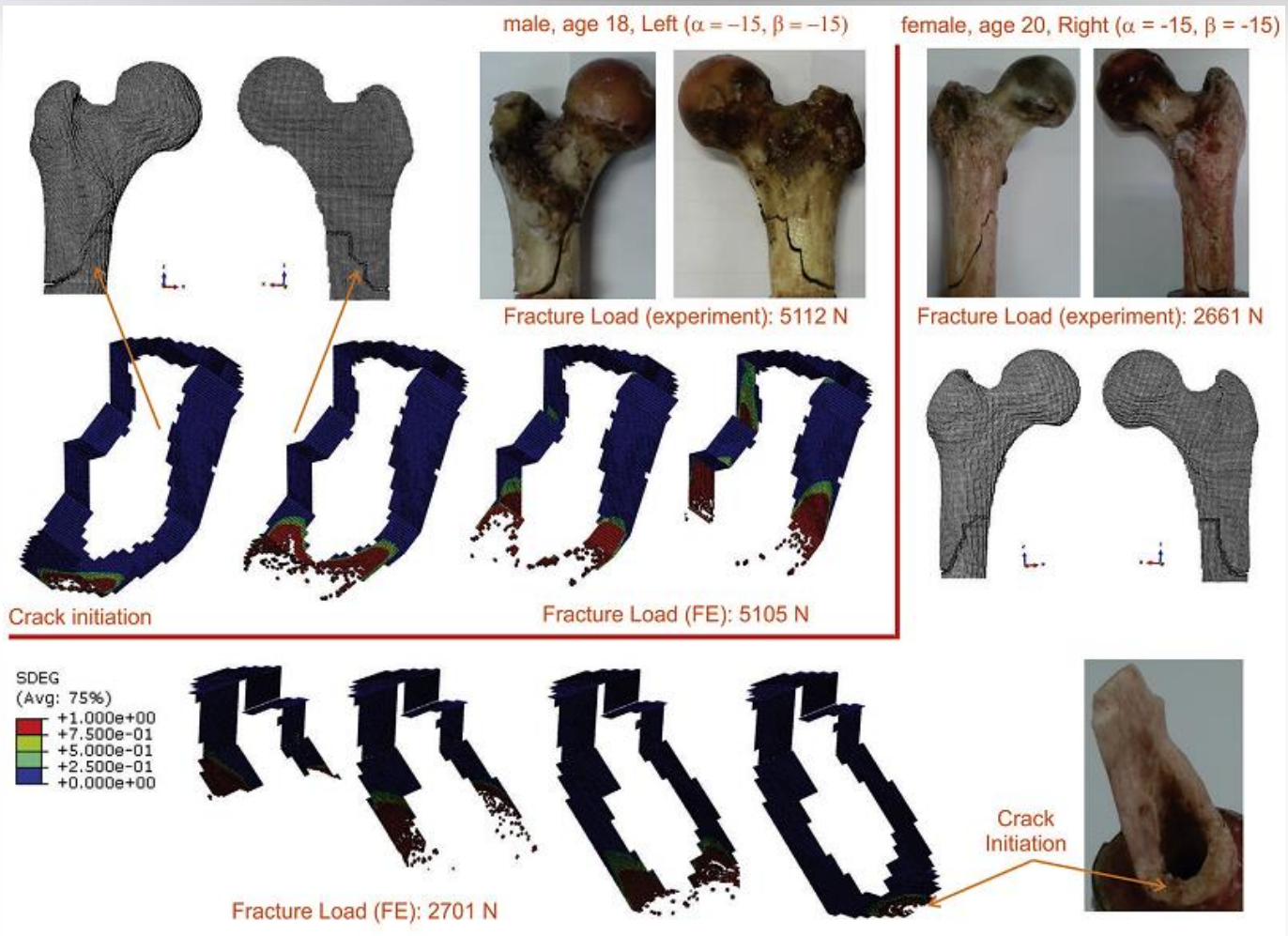


M.Mirzaei, M.Keshavarzian, F.Alavi, P.Amiri, S.Samizadeh, QCT-based failure analysis of proximal femurs under various loading orientation, *Journal of Medical & Biological Engineering & Computing*, 2015, 53(6):477-86.

Defining the fracture properties of femoral cortical bone according to different anatomic quadrants

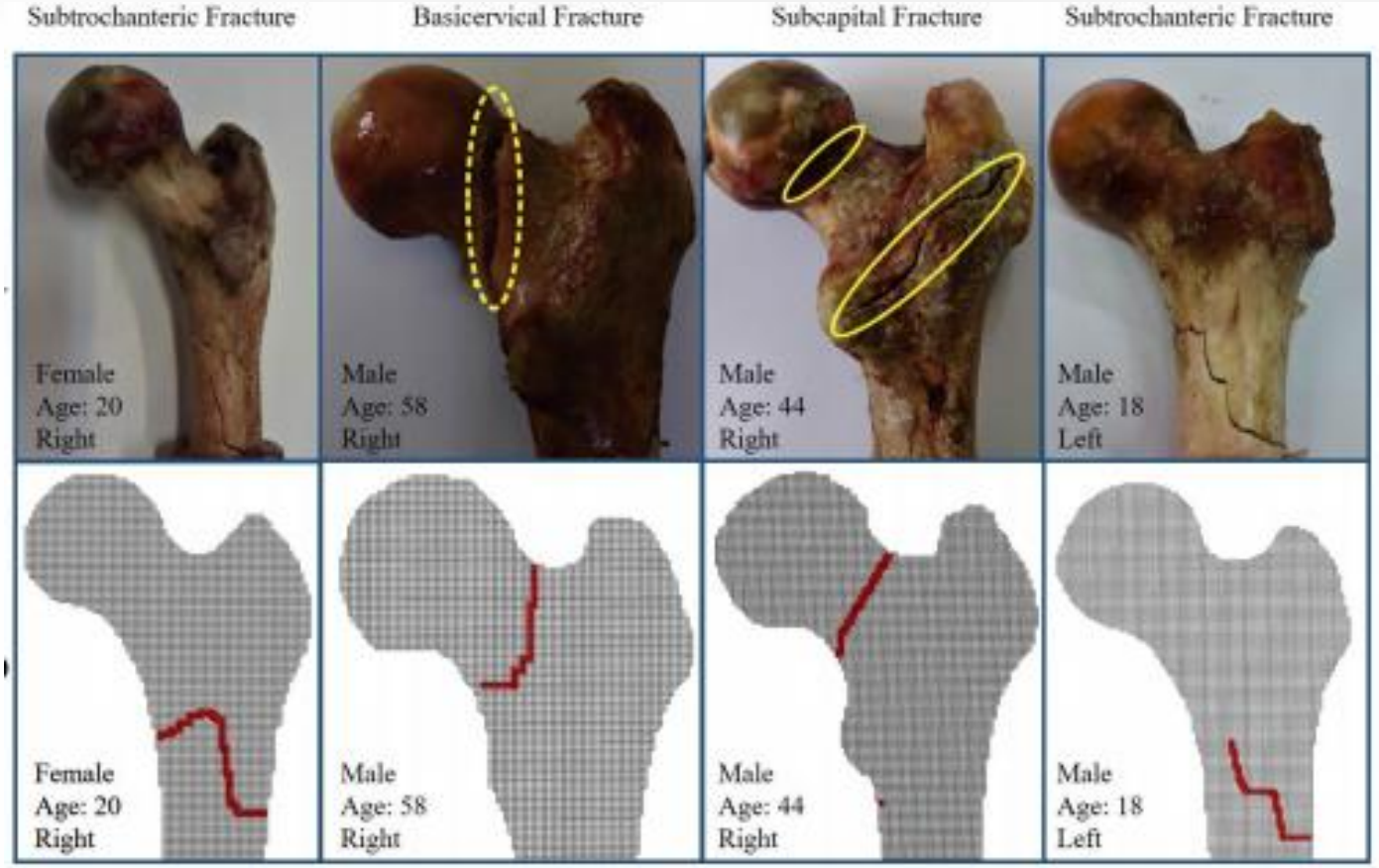


Nonlinear Analysis of femoral fracture using cohesive zone model (CZM)



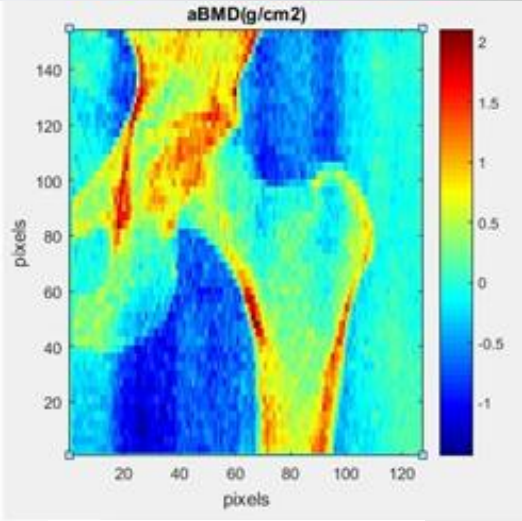
M. Mirzaei, F. Alavi, F. Allaveisi, V. Naeini, P. Amiri, Linear and nonlinear analyses of femoral fractures: Computational/experimental study, *Journal of biomechanics*, 2018, 79: 155-163.

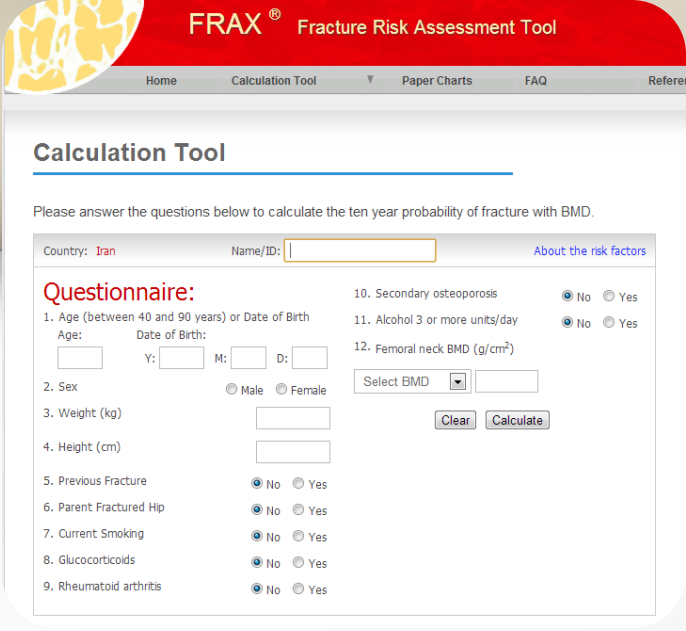
Femoral fracture analysis using XFEM combined with anisotropic damage criteria

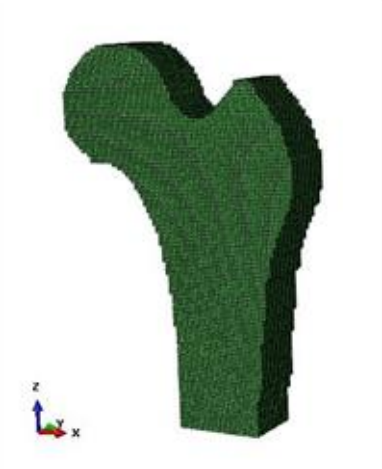


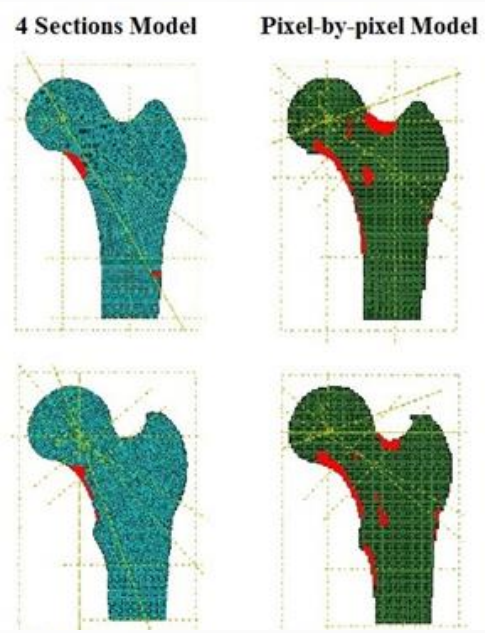
M.Mirzaei, R.Shahbad, F.Alavi, Failure analysis of proximal femurs using XFEM, unpublished data.

Femoral fracture analysis using DXA-based FE model



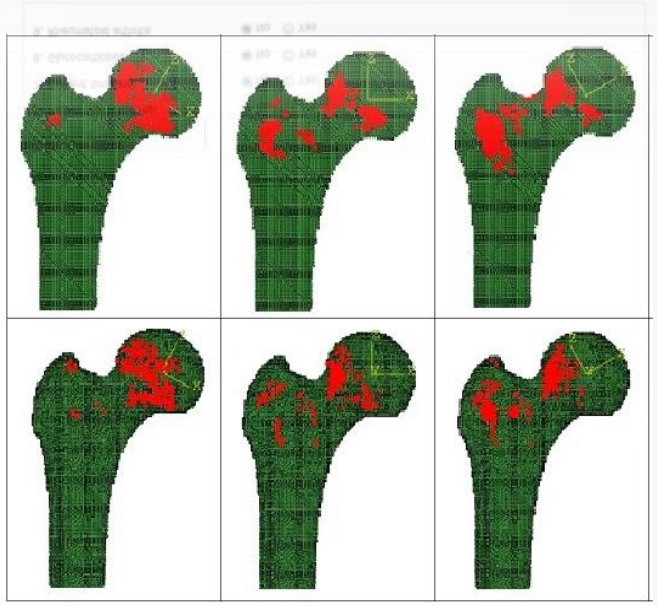






DXA

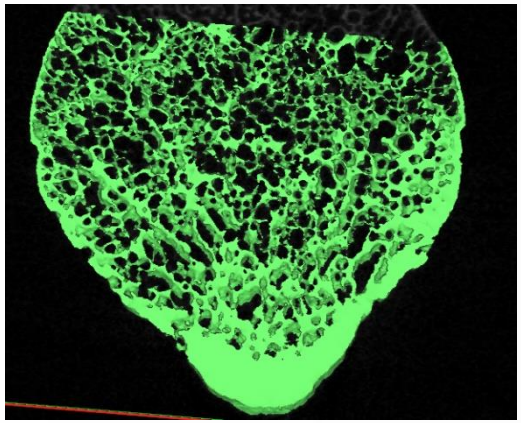
QCT

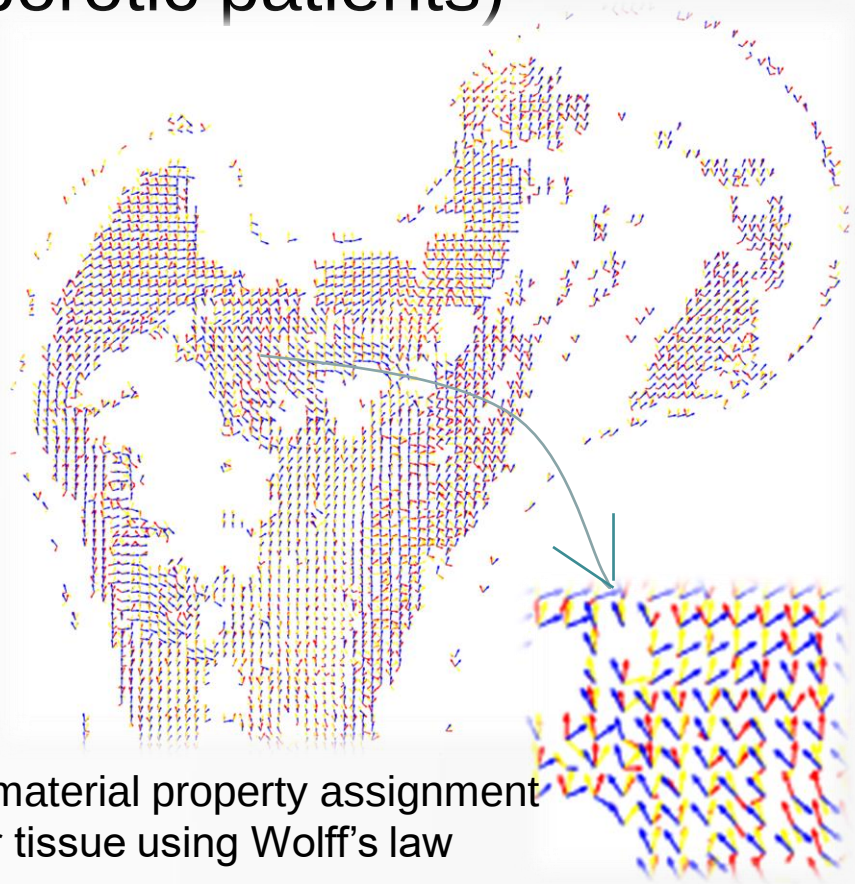


Z. Mohammadi, F. Alavi, Prediction of the femoral fracture location using DXA-based finite element model, submitted to Amirkabir Journal of Mechanical Engineering

Considering the effect of orthotropic material properties in predicting femoral fracture using HR-pQCT imaging (specially for osteoporotic patients)

$$m_i = \frac{1}{\left(\sigma_{prin,1}^{1/4} \times \sigma_{prin,2}^{1/4} \times \sigma_{prin,3}^{1/4}\right)^{1/3}} \sigma_{prin,i}^{1/4}$$





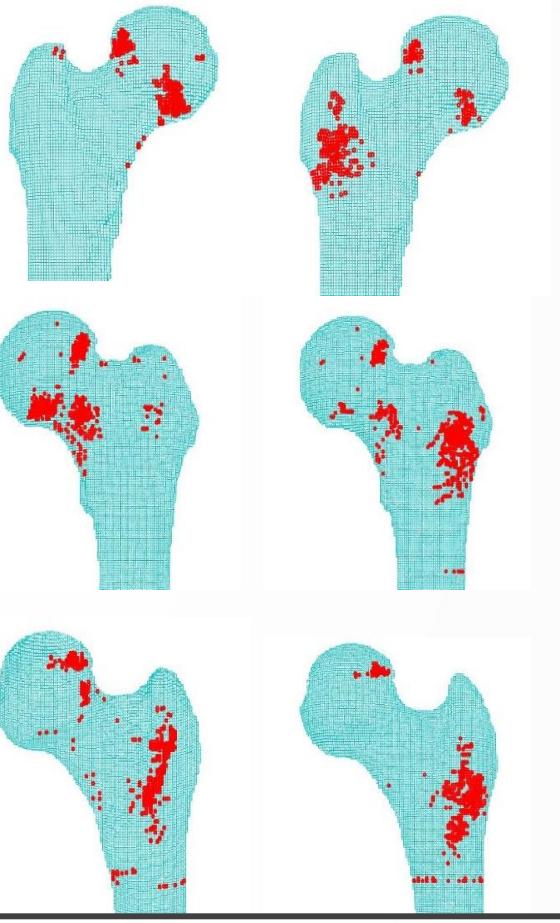
Orthotropic material property assignment of trabecular tissue using Wolff's law

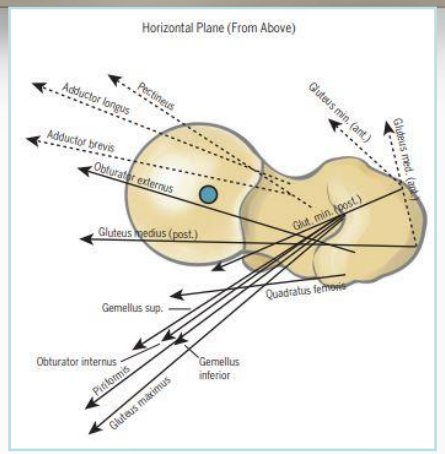
M. Mirzaei, F. Alavi, Bone Strength Analysis considering orthotropic property of trabecular bone tissue, Annual International Conference on Mechanical Engineering (ISME),2017, Tehran, Iran.

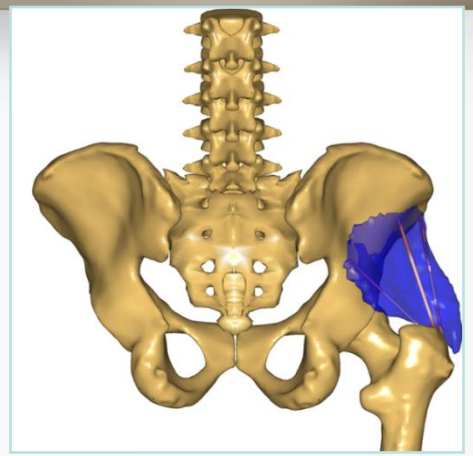
Studying the effect of muscle forces on the femoral fracture pattern

weight

weight + Gluteus Medius Muscle force







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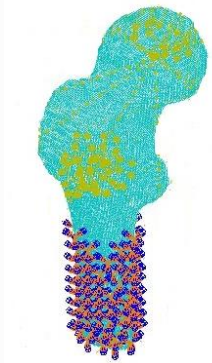

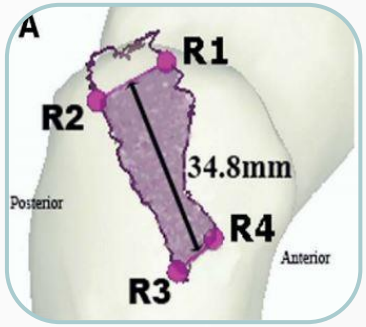

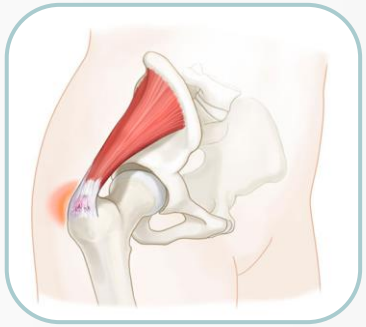

William J. Robertsonet al., Anatomy and Dimensions of the Gluteus Medius Tendon Insertion. Arthroscopy, 2008, 24(2):130-6.

R. Shahbad, F. Alavi, Effects of Hip and Muscle Forces – Specifically Gluteus Medius – on the Femoral Fracture Pattern Analyses, 27th Annual International Conference on Mechanical Engineering (ISME), 2019, Tehran, Iran.

Numerical/Experimental study of composite bone plates under impact loading