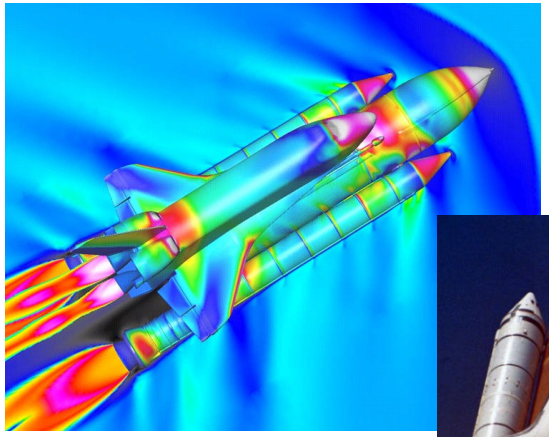
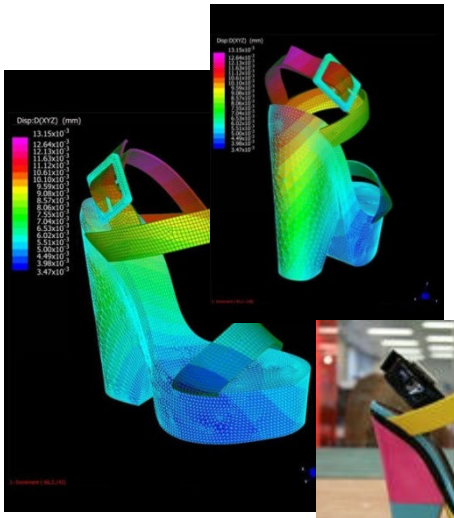
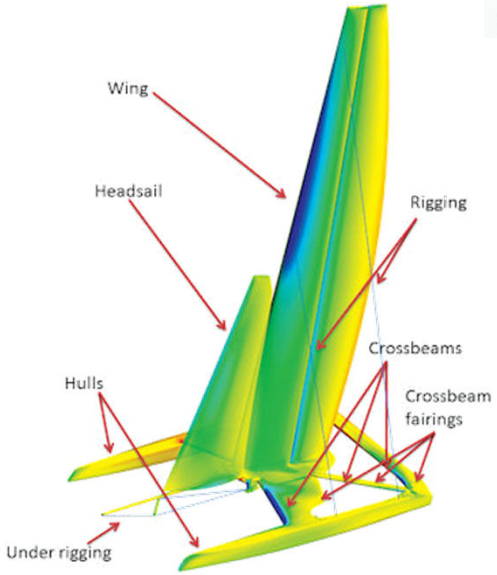
Part 1

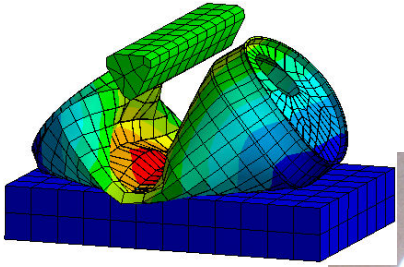
Examples of FEM

Finite Element in *Engineering*





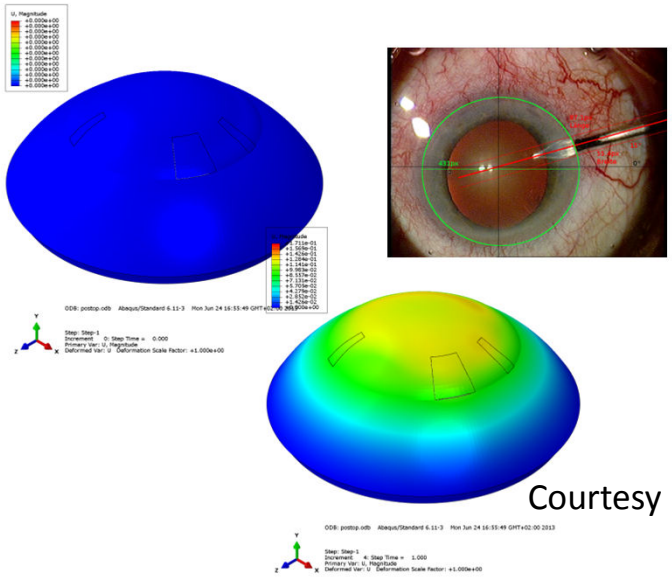




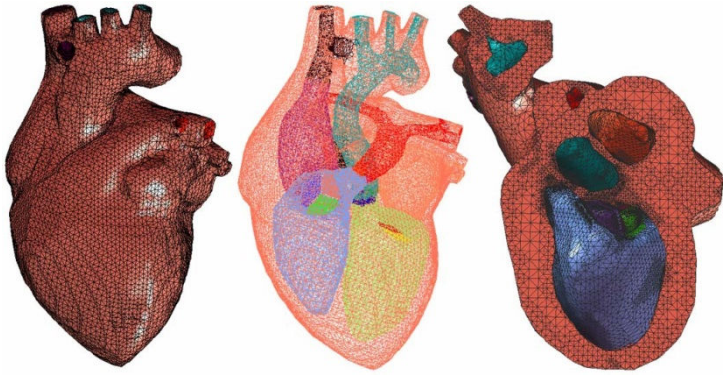
High

Low

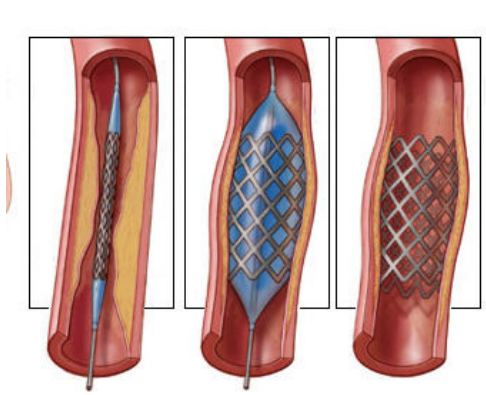
Finite Element in *Bioengineering*



Courtesy H. Studer



Zhang et al. 2004



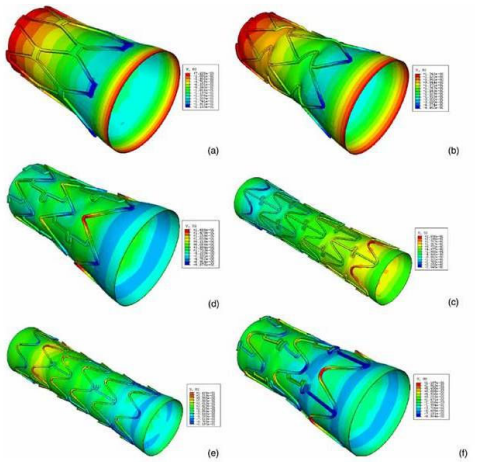
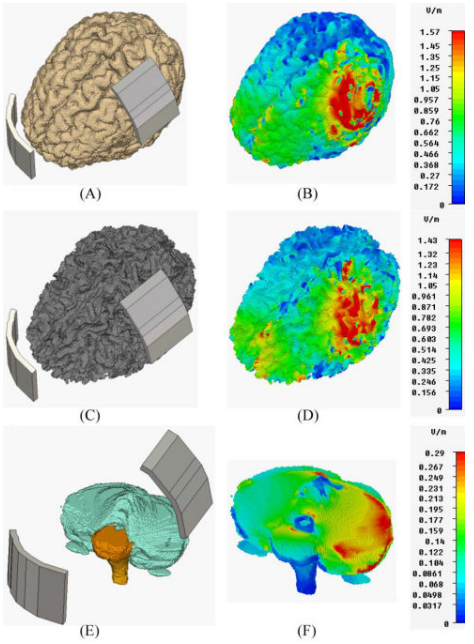


Figure 5. Displacement distributions for 6 different stent designs after balloon expansion [14]

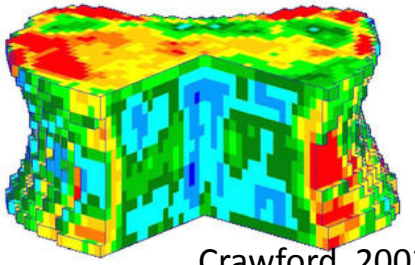


Parazzini et al. 2011

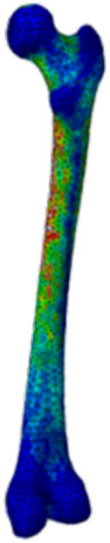
High

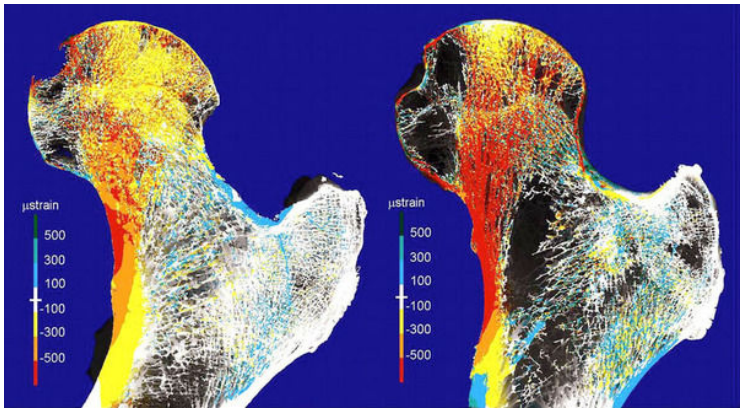
Low

Finite Element in Bones



Crawford, 2003

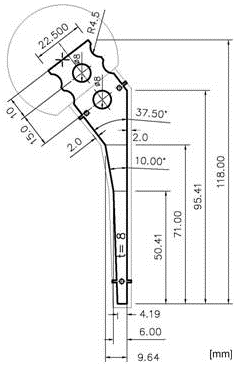


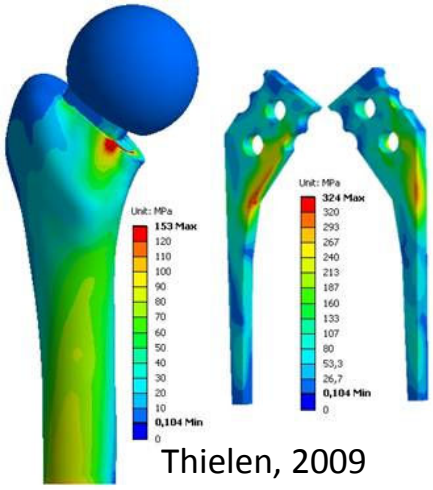


Van Rietbergen, 2003

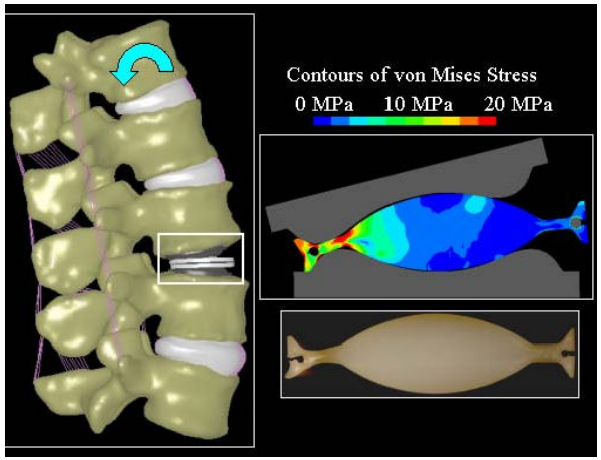
High

Low





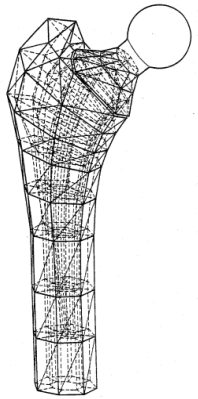
Thielen, 2009

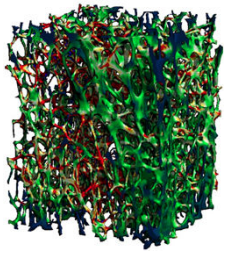


Part 2

FEM in bones

Timeline of FE in bone studies





1947[1]
FEM
Mathematical formalism

1972[2]
FEM in
Bone mechanics

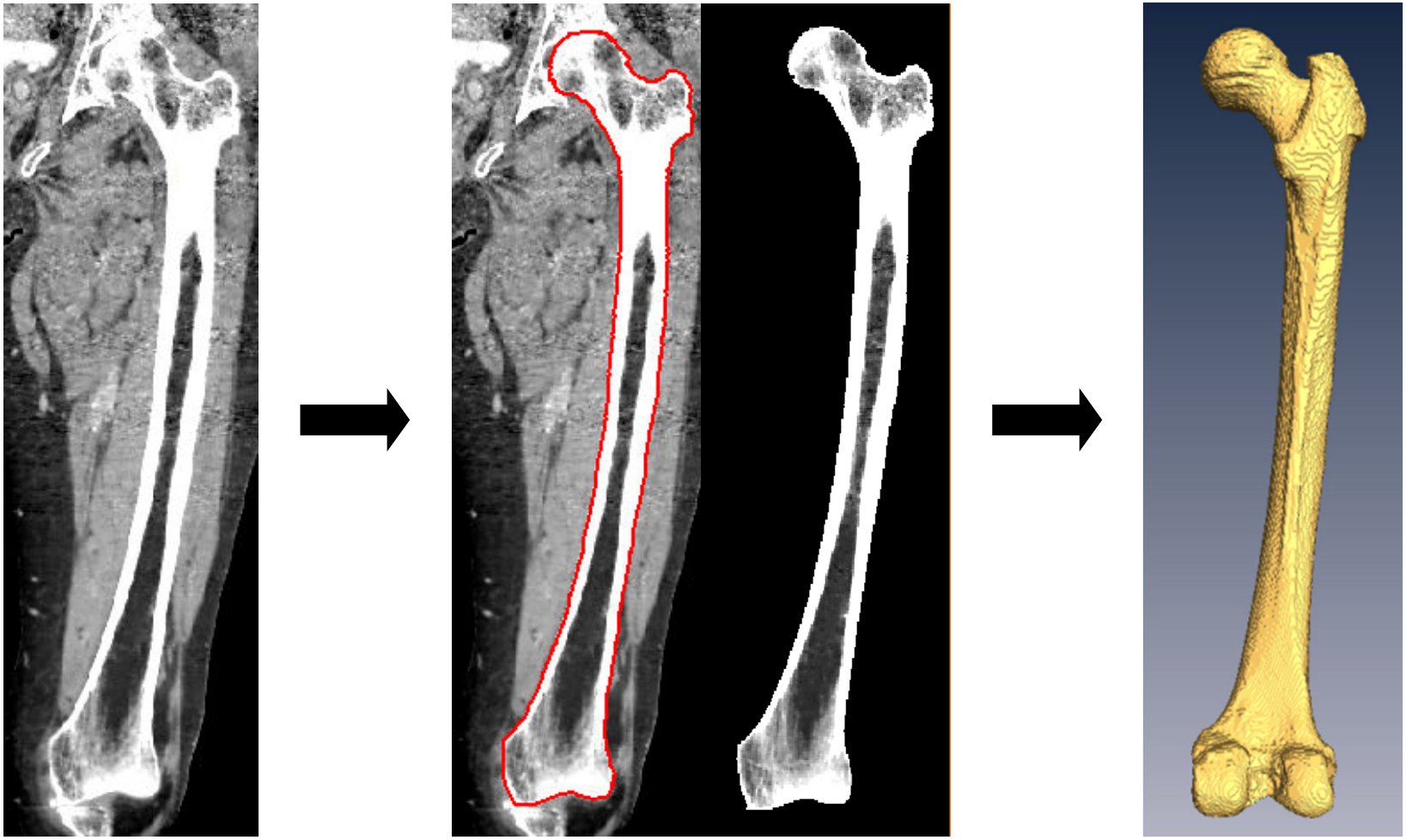
1983[3]
FEM for
Stress analysis
Fracture fixation
Artificial joints

1993[4]
FEM for
Process simulations
Micro-structural modeling

Today
Towards
Patient-specific fracture risk

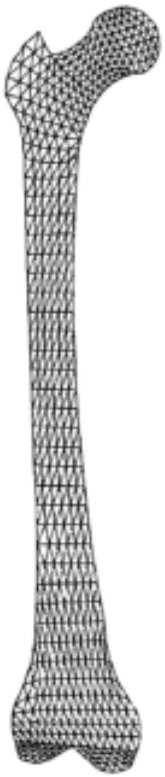
[1]http://en.wikipedia.org/wiki/Olgierd_Zienkiewicz
[2]Brekelmans W. et al. Acta orthop scand. 43 (5), 301–17. 1972.
[3]Huiskes R. J biomech. 16(6), 385-409. 1983.
[4]Huiskes R. J biomech eng. 115(4B), 520-527. 1993.

Geometry (1/2)

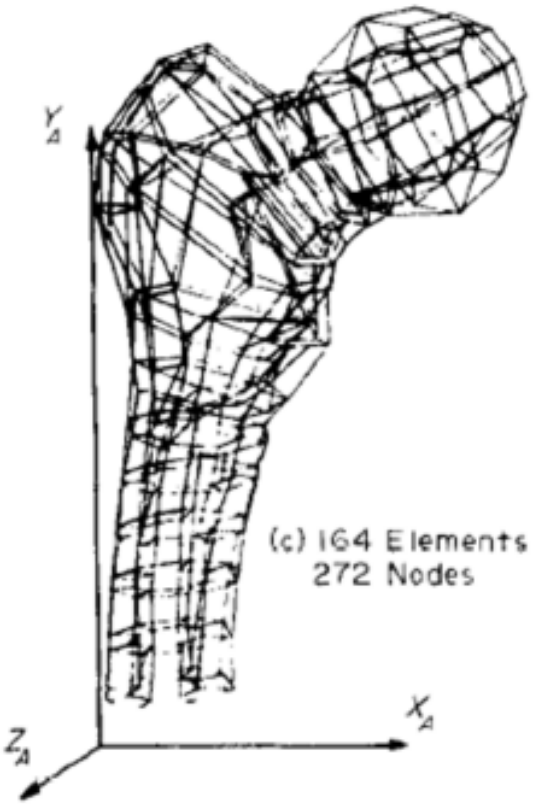


QCT Segmentation Meshing

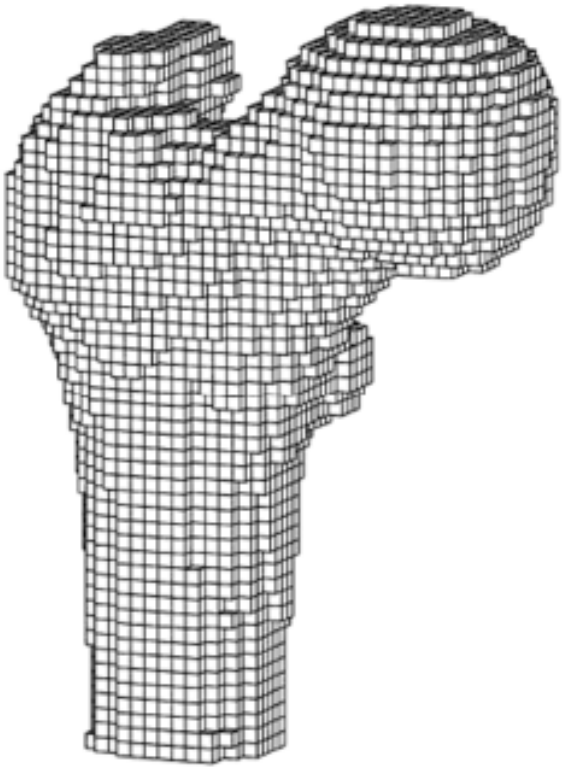
Geometry (2/2)



Triangular surface mesh
[Brekelmans , 1972]



Eight-node volumetric mesh
[Villiappan, 1977]



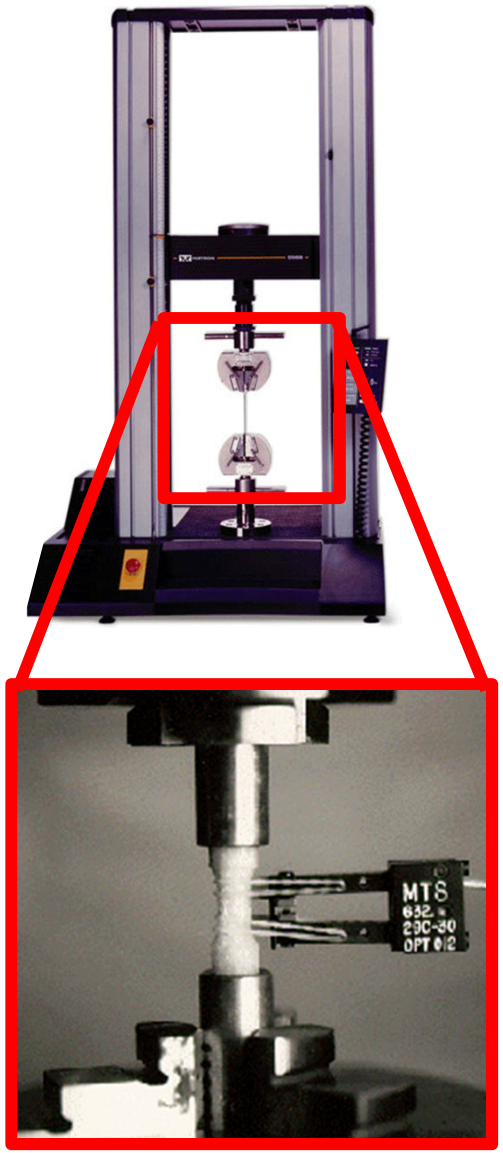
Voxel-based mesh

[Keyak, 1990]

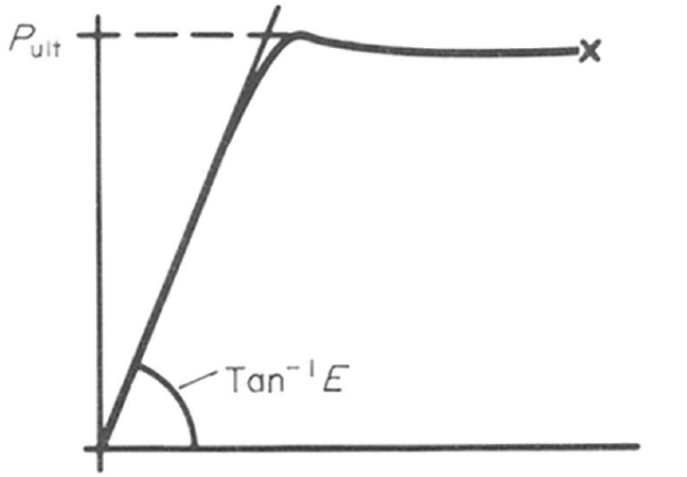
Tetrahedric mesh

[Viceconti, 1990]

Material properties (1/4)

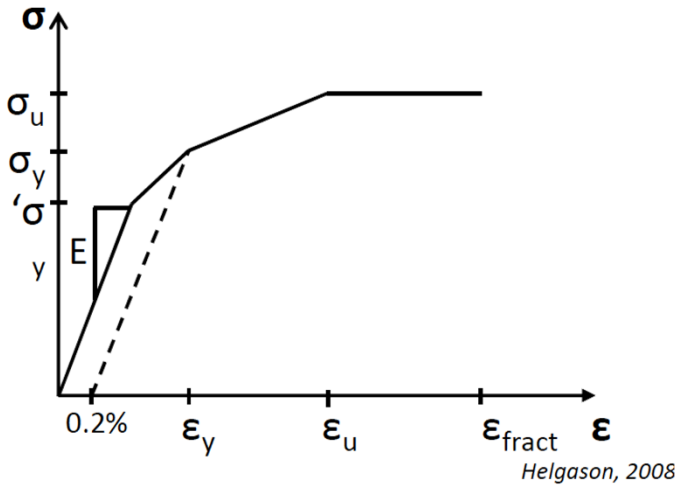


Cortical bone



Reilly, 1975

Trabecular bone

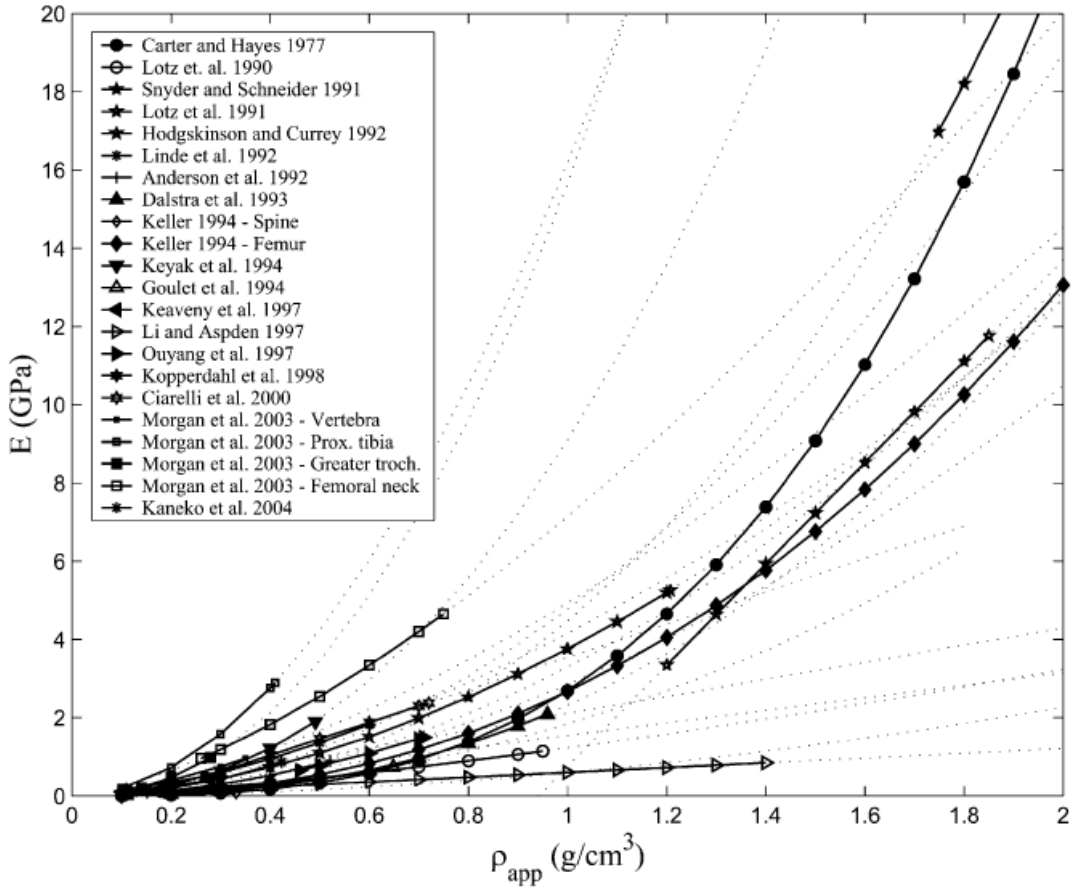


Helgason, 2008

Dependence on age, sex, ethnicity

Material properties (2/4)

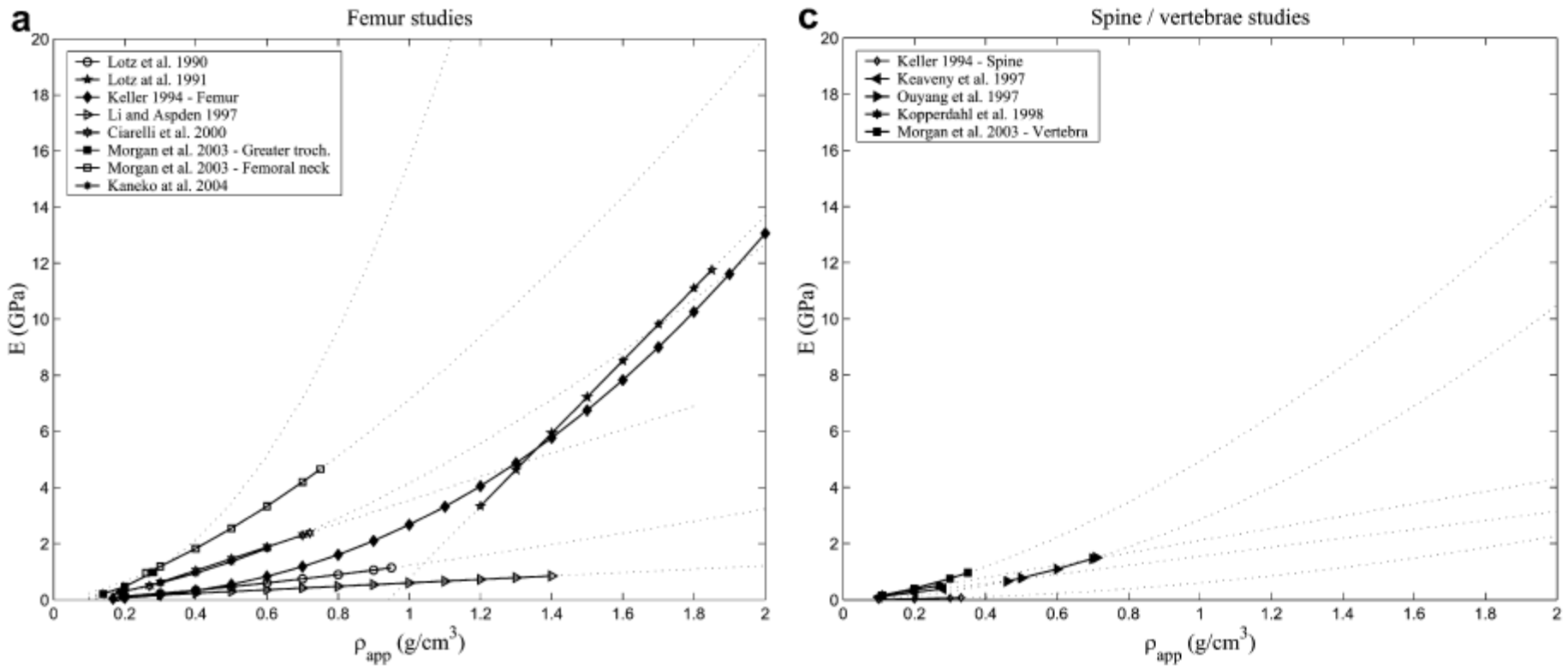
- Density – Young's modulus
  - Power laws: $E = a \rho^b$



[Helgason, 2008]

Material properties (3/4)

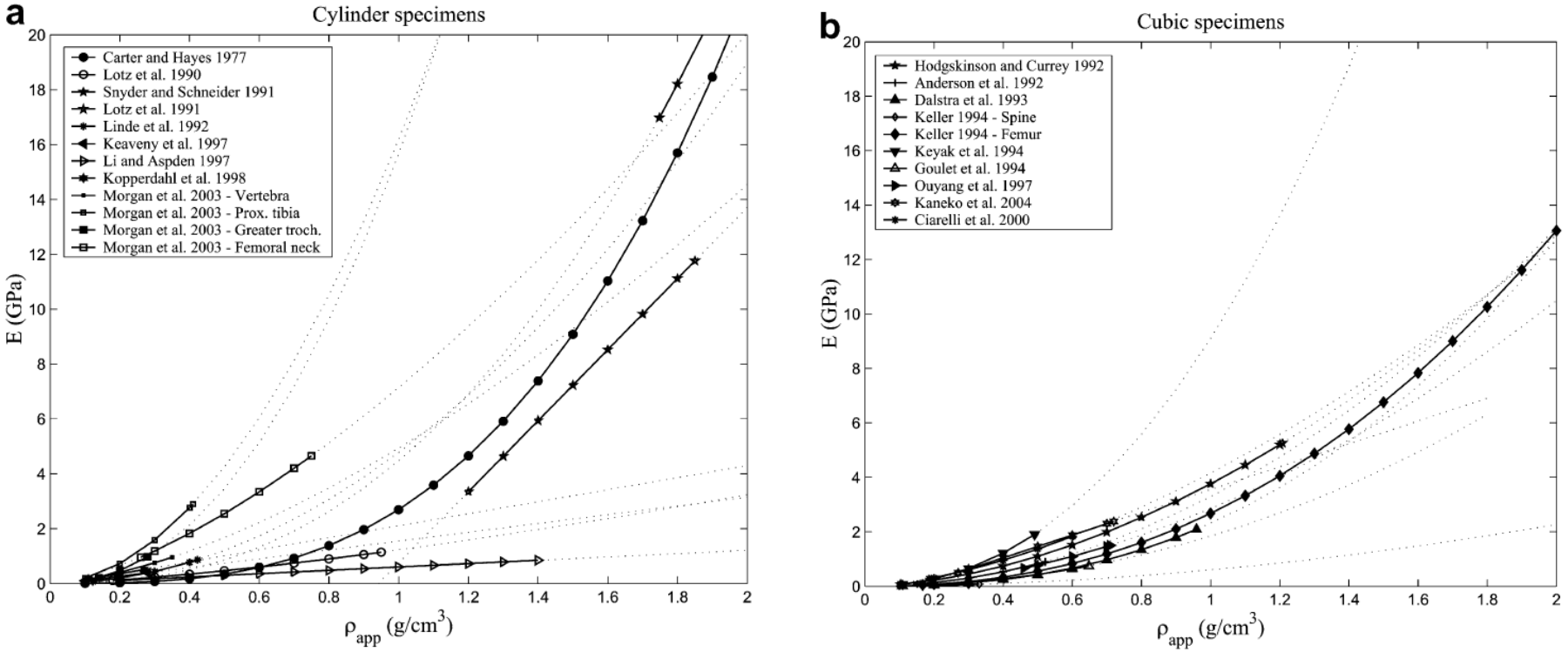
- Density – Young's modulus
  - Dependence on anatomical site



[Helgason, 2008]

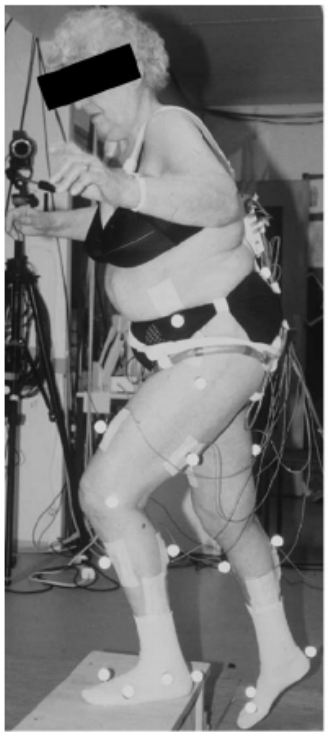
2. Material properties (4/4)

- Density – Young's modulus
  - Dependence on experimental setup



[Helgason, 2008]

Boundary conditions

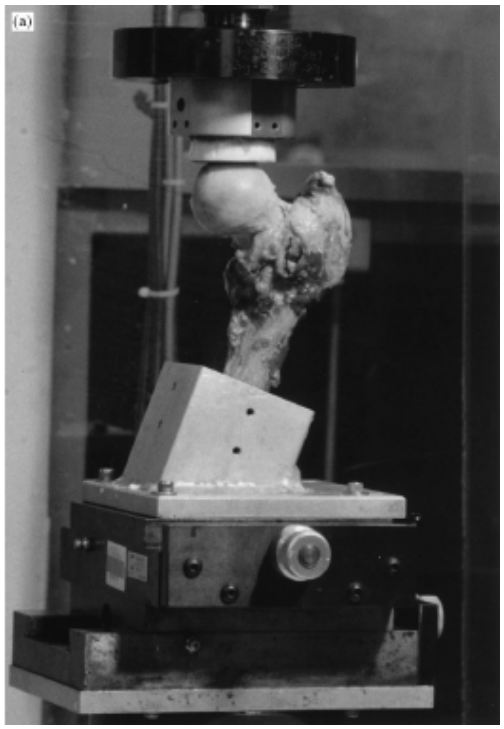


Gait analysis
[Heller,2001]

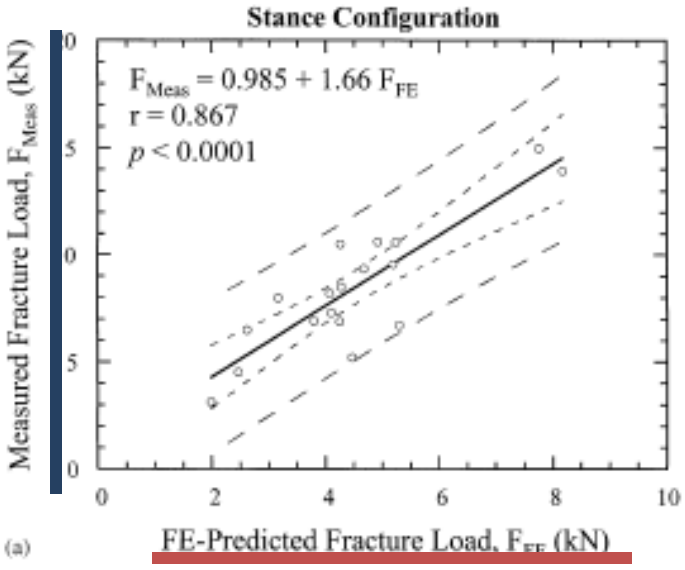
Instrumented hip implants
[Bergmann, 2008]

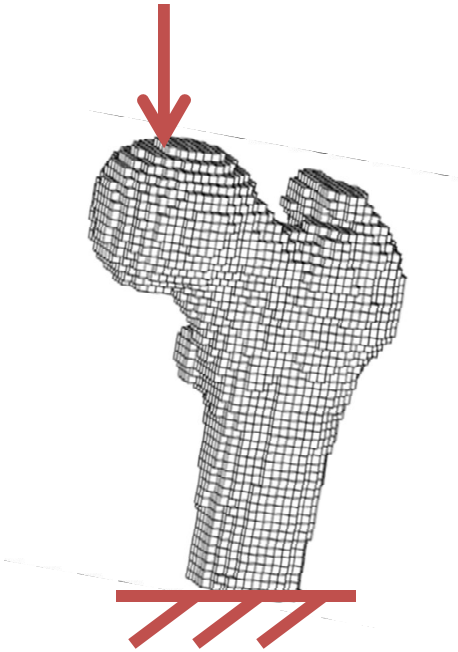
Simulation of interaction between bones and muscles
[Heller, 2001]

Validation - FE



Experiment

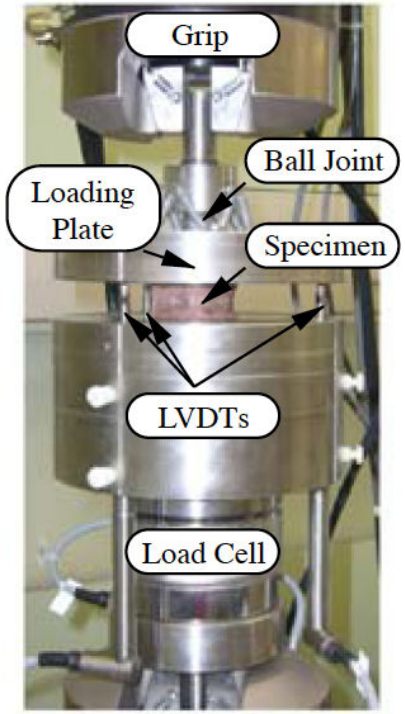




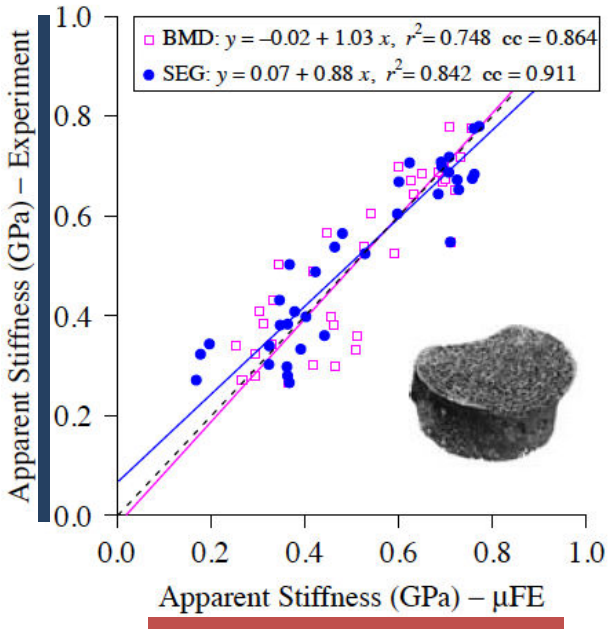
FE simulation

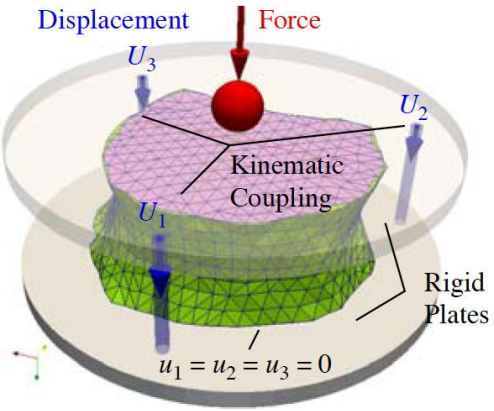
[Keyak, 1998]

Validation - µFE



Experiment





FE simulation

[Pahr, 2011]

Conclusive summary

- FEM is a tool for the investigation of mechanical behavior of bone
  - Simulations of reality
  - Repeatability with different boundary conditions
- Applications of FEM
  - Bone mechanical behavior
  - Fracture dynamics and fracture risk
  - Monitor effect of treatments / drug study design