Accuracy of compression test on excised specimens

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Numerical evaluation of cancellous bone elastic behaviour.

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Problem

- Strain analysis in bone, is required for evaluation of bone strength and analysis of implants.
- Until recently, a porous composite material like bone could only be analysed using apparent properties.
- These are obtained through experimental testing of excised specimen. This method contains (inherent) errors [1].
  - ▷ unsupported side trabeculae
  - ▷ experimental artefacts
- Recent development of μCT and μFE methods (Fig 1.) enables numerical analysis of real-life bone architecture [2].
- Numerical analysis of excised specimen solves some experimental problems, but creates some others [2].
  - ▷ assumption of Hookean material behaviour
  - ▷ numerical errors
- When whole bone model is subjected to physiological loading, the in-situ strains and stresses can be obtained.

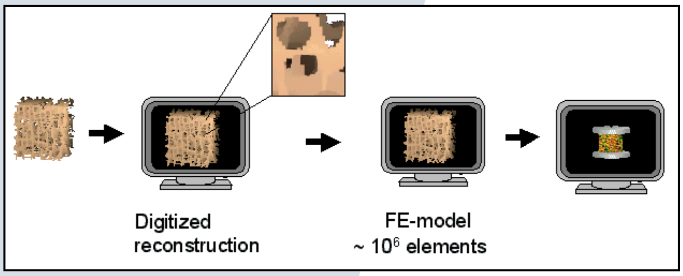

Figure 1 *Creation of the μFE model*

Aims

- Numerical quantification of the inherent error in the computed strain, for
  - ▷ a numerical representation of the experimental method.
  - ▷ a numerical uni-axial strain test, in six directions

Method

- Femur is scanned using μCt, and the image of the trabecular architecture is converted to a μFE model.
- One healthy and one osteoporotic femur were scanned and digitized (Fig 2).
- In each femurhead, seven VOIS were defined.
- Each VOI consisted of 100^3 voxels.
- Three analyses were performed:

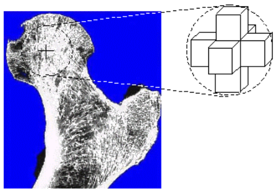

Figure 2 *Position of the VOIs*

In-situ analysis

- Femur was subjected to physiological forces; local stresses and strains were computed.
- The VOIS were extracted from the deformed geometry.
- For every VOI, computed strains and stresses were averaged.
- The averaged values acted as the 'Gold standard' reference.

Standard compression test (Uniaxial stress)

- The VOIs were extracted from the unloaded geometry.
- Every extracted VOI was subjected to free compressions in three directions.
- Side surfaces of the specimen were not prescribed.
- Stiffness matrix was computed from stresses and strains.

Uniaxial strain

- The VOIs were extracted from the unloaded geometry.
- Every extracted VOI was subjected to confined compression in six directions.
- Side surfaces of the specimen were prescribed.
- Stiffness matrix was computed from stresses and strains.

Quantification of the error

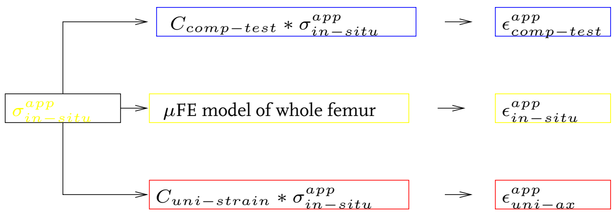

Figure 5 *Computational scheme*

Results

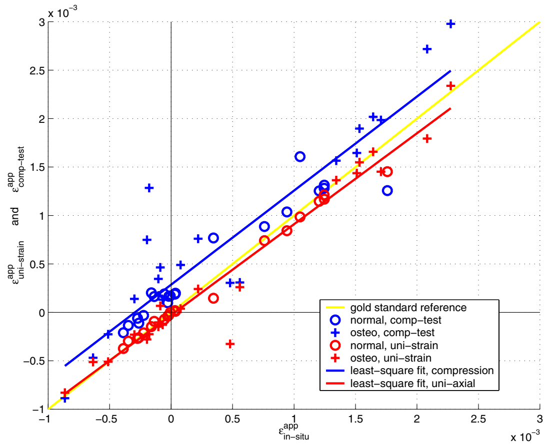

Figure 4 *Correlation plot*
Correlation of in-situ strain versus comp-test strain (blue) and correlation of in-situ strain versus uni-axial (red)

Discussion

- Both methods give a good result
- Compressive forces have absolute error of 10%
- Six compressions gives relative error of 1%

References

[1] Keaveny, T.M. van et.al. (1997), J Orth Res, 15, 101
[2] Rietbergen, B. van et.al. (1996), J Biomech, 29, 1653

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