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Bone mechanical properties derived with FEA is associated with wrist fracture in postmenopausal women

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Customer need

High-resolution peripheral quantitative computed tomography (HR-pQCT) offers new possibilities of predicting bone strength by using micro-Finite Element (µFE) technologies. A unique feature of this approach is that it accounts for the bone micro-architecture rather than density alone. However, it is unknown whether assessment of bone strength by µFE improves the prediction of fractures. In the cited study, performed by Boutroy et al. [1], one of the aims was to investigate whether bone mechanical parameters assessed by µFE analysis could be associated with wrist fractures.

Customer need
Assessment of bone mechanical properties to improve the identification of those at high risk for fracture.

Materials and methods
SCANCO Medical XtremeCT scanner was used to produce the images and SCANCO Image Processing Language (IPL) including Finite Element Analysis Software was used for the analysis.

Results
It was shown that bone mechanical properties derived from the FEA of HR-pQCT images are associated with wrist fracture.
Quantitative values used for analysis were:

- ✓ Stiffness
- ✓ Failure load
- ✓ Von Mises stresses
- ✓ % load between

Materials and methods

The analysis involved 33 postmenopausal women (mean age 73 ± 6 yr) from the OFELY cohort who sustained a fragility fracture within the last 13 years. Each fracture case was randomly age-matched within 1 yr to a control from the same cohort that never had a fracture.

The images used for the analysis were obtained with a HR-pQCT system (SCANCO Medical XtremeCT). The system additionally measures volumetric BMD and microarchitecture. From the images, FE models were generated using Image Processing Language (IPL) software provided by SCANCO Medical and its FE extension IPLFE. In the FE models, different elastic properties were specified for cortical and trabecular bone tissue. Cortical and trabecular bone tissue was automatically segmented based on morphology and density. Fig. 1 shows an example of the separation of cortical and trabecular compartments. For more information about the setting of material properties and bounding conditions see [1].

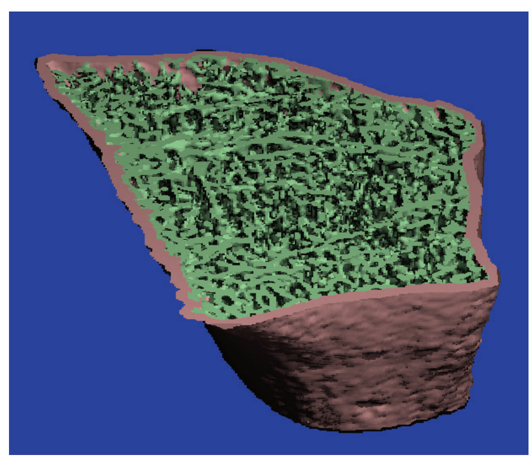


Figure 1: Separation of cortical (pink) and trabecular (green) compartments using the IPL Software.

The estimated failure load was computed based on a criterion developed by Pistoia et al. [2], where

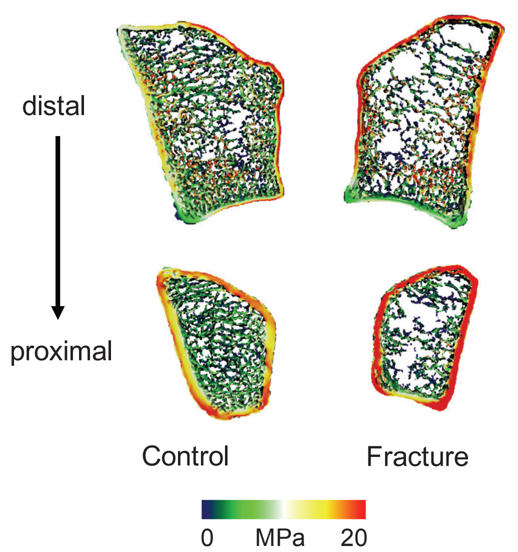
application note

fracture is assumed to occur when 2% of the bone tissue is strained beyond a critical limit of 7000 microstrain. Other µFE-derived variables used in the analysis included the following: stiffness (kN/mm), the percentage of load carried by the trabecular bone at the distal and proximal surface of the volume of interest, and the average and SD values of the Von Mises stresses in the trabecular and cortical bone.

All µFE analyses were performed using the FE-solver included in the IPLFE software.

Results of the analysis

Stiffness and estimated failure load were significantly lower (-15% to -16%), whereas average stresses and the SD of these stresses were higher (6%-23%) in women with fractures compared with controls. Specifically, the SD of trabecular stress was significantly higher in the fracture group, indicating that the local stresses were not as evenly distributed as in the control group. For cortical bone, both the average and SD of the stress were significantly higher in the fracture cases than in controls. Fig. 2 shows the distribution of the Von Mises stresses in the radius of a control and a case.



Cort av stress (MPa):	15.71	19.68
Cort SD stress (MPa):	3.96	5.90
Trab av stress (MPa):	8.15	9.40
Trab SD stress (MPa):	5.38	7.51

Figure 2: Distribution of Von Mises stresses in the bone tissue for a control (left) and a fracture case (right). The colors indicate the stress levels with red for high stresses and blue for low stresses.

µFE showed that, in both fracture cases and controls, most of the load was carried by cortical bone, even at the distal side, which contains mainly trabecular bone.

In the fracture group, the percentage of load carried by cortical bone at this side (63.4%) was higher than in the control group (59.6%) indicating a shift in load transfer from trabecular to cortical bone in fracture cases.

Conclusion

The results indicate that bone mechanical properties derived from FEA of in vivo HR-pQCT images are associated with wrist fracture. A major advantage over other parameters that can be measured with DXA and HR-pQCT is that the parameters obtained from µFE provide a direct estimate of the bone mechanical properties. Altogether, these data provide strong rationale for additional prospective studies testing the ability of FEA based on HR-pQCT to predict fracture risk.

References

More details about this study can be found in:

1. Boutroy, S. et al. *Finite Element Analysis Based on In Vivo HR-pQCT Images of the Distal Radius Is Associated With Wrist Fracture in Postmenopausal Women.* J. Bone Miner. Res. 2008 Mar. 23(3):392-9.
2. Pistoia, W. et al., Estimation of distal radial failure load with micro-finite element analysis models based on three-dimensional peripheral quantitative computed tomography images. Bone 30:842-848.

Numerous references to similar studies can be found on the SCANCO Medical webpage: www.scanco.ch

SCANCO equipment
SCANCO Medical XtremeCT scanner

SCANCO software
Image Processing Language (IPL and IPLFE)

- ✓ Finite Element Analysis Software
- ✓ Automatic separation of cortical and trabecular