QCT-BASED HOMOGENIZED VOXEL FE MODELS PREDICT VERTEBRAL AND FEMORAL FRACTURE LOAD BETTER THAN AREAL BMD

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Introduction

Osteoporotic fractures of the central skeleton represent a major health problem. Nowadays, bone mineral density (BMD) measured *in vivo* is used as a surrogate of bone strength despite its limited accuracy in predicting vertebral and femoral fracture load *in vitro* [Eckstein, 2002]. Quantitative computed tomography (QCT)-based homogenized voxel finite element (hvFE) models can be used *in vivo* to estimate bone strength but need to be validated *a priori* through accurate *in vitro* experiments. The goal of this study was to verify whether the same specimen specific QCT-based hvFE methodology can be used to predict both vertebral and sideways femoral fracture loads and, in particular, if its prediction ability would be better than the one of a standard clinical tool such as areal BMD (aBMD).

Methods

Thirty-seven vertebral body sections and 36 proximal femora were dissected from cadaver donors and scanned together with a calibration phantom using QCT. The QCT images of the vertebral sections were used to compute aBMD by simulating a lateral DXA analysis. Furthermore, every proximal femur underwent a real DXA scan to evaluate the neck aBMD. Afterwards, the vertebral body sections [Dall'Ara, 2010] and proximal femora [Dall'Ara, 2012] were compressed quasi statically by means of a servo-hydraulic testing system to induce typical fractures observed in clinical practice. To generate hvFE models, the QCT images were directly converted to hexahedral mesh (1.3 mm^3 for vertebrae and 3.0 mm^3 for femora) and the average BMD value was converted to bone volume fraction (BV/TV) by means of previously identified calibration equations [Dall'Ara, 2011; Dall'Ara, 2013]. Each element was considered as isotropic and heterogeneous and its material properties were determined as a function of its BV/TV. Material nonlinearities were based on the elastic-damage model developed by [Garcia, 2009] and adapted by [Dall'Ara, 2013]. The applied boundary conditions reproduced the ones of the experiments. The failure load was computed for both experiments (Exp_Fu) and nonlinear hvFE (hvFE_Fu).

Results

If the data for vertebrae and femora were pooled, the hvFE was shown to predicted quantitatively well the Fu_Exp (R^2=0.87, SEE=0.64kN, Figure 1). Conversely, a poor correlation was found between aBMD and Fu_Exp (R^2=0.38, SEE=1.41 kN).

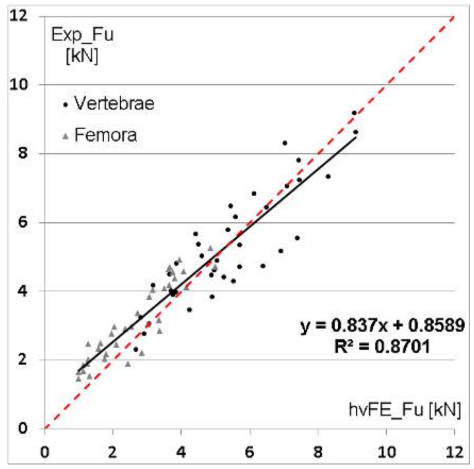

Figure 1: Predictions of experimental versus FE-computed fracture load for both vertebrae (black circles) and femora (grey triangles). The dashed line shows the 1:1 relationship.

Discussion

The results of the present study show that the same QCT-based specimen specific hvFE model can predict vertebral and sideways femoral fracture load with a fair accuracy also when the anatomical sites are pooled together. However, for *in vivo* applications, the better accuracy of hvFE must be weighted against the larger radiation dose required to perform QCT scans compared to DXA.

References

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