ESTIMATION OF FEMORAL FE STRENGTH FOR THE FRACTURE PREDICTION IN RETROSPECTIVE AND PROSPECTIVE STUDIES
Cristina Falcinelli1,2, Enrico Schileo2, Sigurdur Sigurdsson3, Vilmundur Gudnason3,4, Fulvia Taddei5
1 Department of Civil Engineering, University of Rome Tor Vergata, Italy; 2 Computational Bioengineering Laboratory, Rizzoli Orthopaedic Institute, Italy; 3 Icelandic Heart Association Research Institute, Kopavogur, Iceland; 4 University of Iceland, Reykjavik, Iceland; 5 Medical Technology Laboratory, Rizzoli Orthopaedic Institute, Italy

Introduction
Finite element (FE) models (FEM) from CT data are promising to assess bone strength (FEBS) and the risk of fracture in vivo. They have demonstrated a high accuracy in predicting bone strains and bone strength in vitro. However, when tested on clinical cases [Amin, 2011; Keyak, 2011; Orwoll, 2009] they did not show a clear superiority over areal bone mineral density (aBMD). The aim of this work is to explore the clinical predictivity of FEBS derived from a validated subject-specific FEM procedure [Schileo, 2008] in a case-control retrospective study (RS) and in a nested case-control prospective study (PS).

Methods
Retrospective Study: 22 incident low trauma proximal femur fractures (F) and 33 controls (NF) were enrolled at Istituto Ortopedico Rizzoli. All patients were osteopenic or osteoporotic and received a full femoral CT (in acute conditions for fractured cases) and a DXA exam.
Prospective study: 21 women on which proximal femur fractures (F) were prospectively observed, and 45 sex and age-matched controls (NF) were selected from the AGES-Reykjavik Study. For each individual, baseline proximal femur CT scans and simulated DXA aBMD values from QCT were available.
The FE models were generated from CT [Schileo, 2008]. FEBS, evaluated in a number of quasi-axial configurations to mimic the in vivo variability of hip reactions, was defined as the minimum load inducing on the femoral neck surface an ε>εlim [Bayraktar, 2004]. We tested the ability of FEBS and aBMD to: 1) discriminate between fracture cases and controls; 2) individually classify cases at risk.

Results and Discussion
In both studies, FEBS had a limited correlation with aBMD (Spearman r~0.5 vs ~0.8 reported in [Orwoll, 2009; Amin, 2011]). FEBS and aBMD showed a lower mean value in F group compared to the NF group in both studies. The mean differences were: 1) notably higher for FEBS in the RS (33%, p <0.0001, vs 12% for aBMD, p =0.01); 2) slightly higher for FEBS in the PS (19%, p-value <0.0003, vs 15% for aBMD, p-value <0.004). The mean FEBS differences were higher than [Keyak, 2011].
To test the ability of FEBS and aBMD to individually classify cases, logistic regressions and ROC curves were derived for FEBS and aBMD obtaining: 1) in the RS, a superiority of FEBS vs aBMD in classifying F and NF (AUC=0.88 vs 0.71, higher than [Amin, 2011]) and 2) in the PS, a slightly better performance for FEBS than aBMD (AUC=0.78 vs. 0.72). though the maximum classification ability reached so far in this study (AUC=0.80, combining FEBS and aBMD in the regression) does not improve over the existing literature. However, when including both FEBS and aBMD in the regression, in both studies only FEBS was retained as statistically significant.
These results confirm the potential of the proposed FE method to clinically identify fractured cases, despite two limitations: 1) in the PS, the change of bone material properties with time was not modelled (future work); 2) in both RS and PS, falls to the side were not modelled (ongoing).

References
Amin et al, JBMR, 26:1593-1600, 2011
Keyak et al, Bone, 48: 1239-1245, 2011
Orwoll et al, JBMR, 24: 475-483, 2009