FEM-DERIVED FEMORAL STENGTH IS A BETTER PREDICTOR OF HIP FRACTURE RISK THAN BMD IN THE AGES RS COHORT

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Introduction

Hip fracture risk assessment based on areal bone mineral density (aBMD) is known to only identify about 50% of individuals that fracture their hip. Finite element models (FEMs) based on X-ray computed tomography (CT) scans can are a better predictor of *ex-vivo* measured proximal femoral strength than aBMD. However, these models have not been demonstrated to be superior to aBMD in predicting hip fracture risk in clinical cohorts using only information gathered at baseline. The FEMs have only been shown to be superior in assessing fracture risk when using data collected post-fracture [1] or with biased cohorts that do not include subjects with normal bone T-score [2]. In this study we compare FEM derived femoral strength and aBMD in terms of their ability to classify hip fractures in the AGES Reykjavik Study (RS) cohort.

Methods

CT-based explicit FEMs were built for 573 subjects (228 males and 345 females) of the AGES RS. 189 of these subjects suffered a hip fracture during the subsequent 5-7 year follow up period. Non-linear literature-based material properties were assigned to the FEMs based on CT grey scale values [3]. Each femur was loaded under 12 sideways fall impact alignments (Fig. 1). Femoral loading was achieved through frictionless contacts between the femur and the supports at the greater trochanter and femoral head. The supports were free to move translationally in X- and Y-direction. Rotations of the supports were full constrained. The femoral head support was displaced in the Z-direction at a rate of 1 m/s, while no translation in Z was allowed for the trochanter support. Beams were used to connect the proximal femur the knee point, which only allowed rotations in Y-direction. Classification of hip fractures was compared between femoral strength (S) and aBMD using area under the receiver-operator curve (AUC).

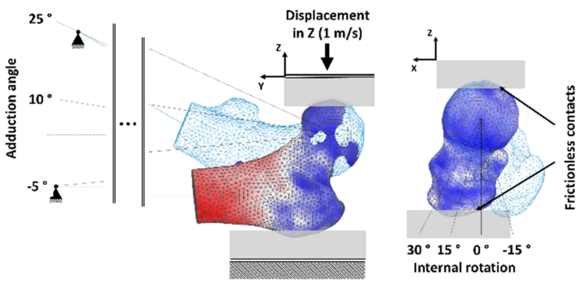

Figure 1: Boundary conditions for femur FEMs. 12 different loading angles (4 internal rotation angles x 3 adduction angles) were modelled.

The ratio (S_{ratio}) between maximum femoral strength (S_{max}) and minimum femoral strength (S_{min}) was calculated to analyze the sensitivity of femoral strength to the loading direction. Squared Spearman's coefficient of correlation (R_S^2) was used to quantify the variance in ranking for hip fracture classification depending on loading alignments.

Results

The AUC based on FEM derived strength was found to be significantly higher than the AUC of aBMD for 10 out of 12 loading directions (Tab. 1). The ranking based on strength between loading direction was highly correlated $R_S^2 = 0.71$-0.99. The sensitivity of the femur to the loading direction was subject dependent (S_{ratio} = 1.01-2.10).

	Male N = 228	Female N = 345	All N = 573
aBMD	0.725	0.681	0.714
$S_{10/0}$	0.784**	0.740**	0.754**
S_{min}	0.760	0.718*	0.736
S_{max}	0.783**	0.734**	0.753**
S_{mean}	0.776**	0.734**	0.749**

*Table 1: AUC for classifying hip fractures. $S_{10/0}$ is the femoral strength at 10° adduction and 0° internal rotation. Fracture classifications were compared to total hip aBMD: * $p < 0.05$; ** $p < 0.01$*

Discussion

Using only baseline information in a large clinical cohort, we have shown a significant improvement in AUC for FEM-derived proximal femur strength compared to aBMD. The sensitivity of femoral strength to different loading directions was subject-specific, highlighting the importance of analyzing multiple loading scenarios. This study adds credibility to the use of FEM-based hip fracture risk assessment in clinics. In the future, these models can be used to develop an in-silico selection of personalized preventive treatment.

References

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