Inter-individual variability of bone density and morphology distribution

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Introduction
Finite element modeling has become a standard pre-clinical tool for the evaluation of bone and bone-implant configurations. In such models, empirical laws are used to calculate the bone mechanical properties from the bone density and other micro-structural parameters such as bone fabric which are derived from CT images. However, for a thorough pre-clinical evaluation, the models used should be able to represent the range in bone quality that can be expected in a patient population. For this, information is required about the variation in bone density and micro-structure in a population at the location of each element.

Objective
The goal of this study is to investigate the local variability of bone density and micro-structural parameters between subjects using a new approach.

Materials and methods
Human proximal femurs of 24 subjects (57.7 ± 9.4 yrs.) and T12 vertebrae of 20 subjects (80.9 ± 9.9 yrs.) were scanned on a micro-CT system (Scanco, Switzerland). A pre-defined mesh template was morphed to each micro-CT scan to create iso-anatomic subject-specific continuum models [1]. For each element within the cancellous bone, a spherical region around the element center with a radius of 2 mm was defined. For that region, bone volume fraction (BV/TV) and morphological parameters (Tb.Th, Tb.N, Tb.Sp, SMI, DA) were determined and assigned to the element. Then, for each parameter and each element, a coefficient of variation (CV) was calculated for the subjects. An overview of the procedure is shown on Fig 1.

Results
The mean volume fraction in the proximal femur and its CV are displayed in Fig. 2.

Discussion
In this study, we quantified the spatial variation in proximal femur and T12 vertebra volume fraction and architectural parameters. The results indicate considerable variability in bone morphology between subjects for the femoral neck and trochanter region. Since hip implants typically are anchored in these regions, applying realistic variations to material properties in these regions is important to accurately evaluate implant behavior with FE models. Also for T12s, considerable variation of morphological parameters between subjects should be considered in T12 augmentation processes such as kyphoplasty and vertebroplasty.

References