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COMPARISON OF VOXEL-BASED MICRO FE AND DIFFERENT SURFACE-BASED HOMOGENIZED FE MODELS OF HUMAN VERTEBRAL BODIES

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ABSTRACT

Finite element models are well suited to investigate the mechanical behavior of bones and bone implant systems. Two major bone model types are mentioned in the literature: Surface-based homogenized models ([1], [2], [3]) and computationally intensive voxel-based high-resolution FE models ([4] [5]). Surface-based homogenized models suffer from a simplistic modeling of the cortical shell and density-based trabecular bone modelling. In some studies the shell is not modeled ([6], [3]) or a constant shell thickness is assumed ([1],[2]). The homogenized model could be of voxel type ([6],) or surface type ([1], [3],[2]). In contrast, high-resolution FE models contain the shell automatically. An improved understanding of the biomechanical role of the cortical shell in a bone makes it necessary to distinguish both bone types ([5]).

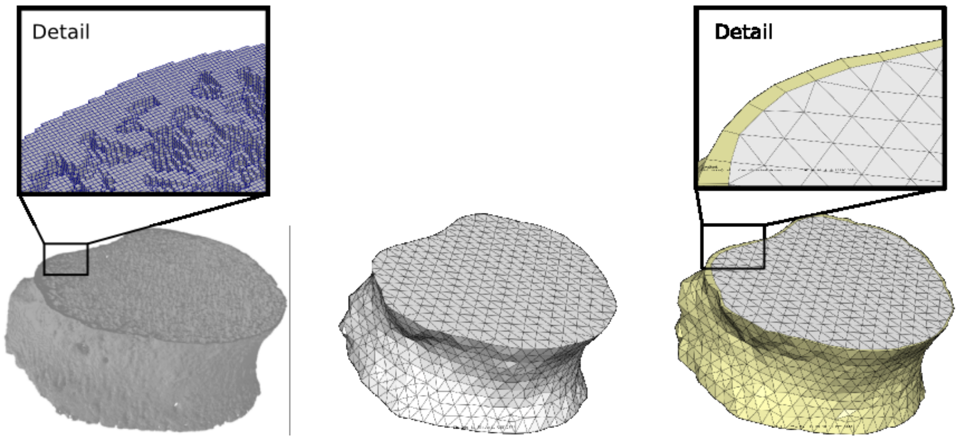

Figure 1: Models: Voxel-based Micro FE with detail (left), surface-based homogenized FE models without shell (middle) and anatomy-specific shell (right).

In this work high-resolution FE models (Figure 1 left, similar to [5]) of 12 elderly vertebral bodies from a high-resolution CT (Xtreme CT, SCANCO Medical, Switzerland) are compared to three different surface-based homogenized models, namely:

1. BVTV based, isotropic cancellous bone material without cortical shell (Figure 1, middle).
2. BVTV based, isotropic cancellous bone material with anatomically correct cortical shell (Figure 1, right).
3. BVTV and fabric based, orthotropic cancellous bone material with anatomically correct cortical shell (Figure 1, right).

The first novelty of this study from the geometrical point of view is that the digitized cortical shell information from high-resolution CT scans (82 μm resolution) is used to build up surface-based homogenized bone model. From the material point of view, the second novelty is that the architectural information is used for fabric-density-based trabecular bone material cards ([7]). In such a model the cancellous region is modelled with homogenized orthotropic continuum elements. The third novelty is that the tissue fabric-density relationship is based on a numerical calibration study using 60 cubical finite elements models (6mm side length with 82 μm) which are cropped from the vertebrae. A new set of periodic compatible mixed boundary conditions ([8]) is applied in order to get the full orthotropic stiffness tensor and finally the tissue material parameter for the fabric-density-based model. Thus errors from experimental modulus-density relationships are avoided. All models are analyzed under compression and simple shear loading and the vertebral stiffnesses are computed. In that way efficiency, accuracy and limitations of the different models are compared.

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