

# Abstract

Cortical bone tissue is the responsible of giving support and structure to vertebrates. For that reason, understanding and analyzing its behavior is needed from each different hierarchical level that composes it. The lower the structural scale is, the greater the complexity and scarcity of studies in literature. These studies are relevant for understanding, preventing and solving important health problems that affect human beings.

From a mechanical point of view is interesting to evaluate and apply engineering numerical tools to analyze complex materials as biological tissues, increasing the state of the art in different disciplines that can be applied in numerous fields as material science, biomechanics, numerical methods, medicine and more.

In this Thesis the mechanical behavior of cortical bone at microstructural level is analyzed, with finite element models of its basic structure, the osteon. The microstructure of osteons, composed of mineralized collagen fibrils in layers with different orientations disposed concentrically around blood vessels is considered in the models for the calculation of elastic properties and failure criteria definition.

For obtaining elastic properties, the use of micromechanical finite element models is considered, with heterogeneous composition for both mineralized col-

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lagen fibrils (at nanostructural level) and lamellar level (at sub-microstructural level).

The failure analysis for realistic geometries is applied after comparing different models that involve, on one hand the growth of microcracks with contact conditions and on the other, degradation of elastic material properties by user subroutines of the finite element code, the latter being the one that brings better results from a computational cost viewpoint. Therefore an interesting alternative is here presented that can be used to evaluate the damage propagation at three-dimensional level, which with other methods as X-FEM can be computationally unaffordable.

Composite materials failure criteria are applied to osteon analysis and the results are related with experimental tests from bibliography, showing the relevance of shear stresses between lamellae for failure initiation and propagation. In a two-dimensional study it is also shown the important role of osteocyte lacunae in the failure initiation, what is interesting from a cellular mechanotransduction approach.