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MULTISCALE ANALYSES OF OSTEOCHONDRAL SCAFFOLD WITH ETHEROGENEOUS POROSITY AND MATERIAL CONSTITUTION

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Tissue engineering has great potential in providing the appropriate replacement of diseased articular cartilage with a compatible substitute which is able to grant a reliable fixation into the joint defect and integration with the subchondral bone[1].
The replaced engineered tissue, not only needs to be fully biocompatible with the individual subject in which they are implanted, but also requires specific mechanical and structural properties for adequate functioning and integration within the body. One of the most widely adopted strategies relies on the use of an artificial structure, also regarded as scaffolds, having the function of supporting stress under loading conditions and promoting the bio-mineralization process and the formation of new tissue.
The resulting tissue constructs generally exhibits an overall composition that resembles that of the original tissue, but the tissue structure at nano and micro scales may be considerably different from that of the native tissue. This difference may compromise proper functionality and integration of the implants[2].
In this work an inhomogeneous monolithic scaffold is analyzed with 3 distinct phases, a chondral phase, an intermediate phase and a subchondral (bony) phase[3]. Each of the three layers is characterized by different constituents and architectural features in terms of average porosity. In particular, the chondral phase is the superficial layer composed by 100% deantigenated type I equine collagen. The intermediate layer (tide mark) and the bony layer instead, are formed by a randomly oriented network of collagen fibers with magnesium-enriched HA inclusions of different shapes (see table 1).

MATERIAL LAYER	HA volumetric fraction f_{HA}	Collagen volumetric fraction f_{col}
Chondral	0	100
Intermediate	0.4	0.6
Subchondral	0.7	0.3

Table 1: material compositions for the three layer of the HA/Collagen osteochondral tissue substitute.

The mechanical properties of the multilayer scaffold is estimated by means of a multiscale hierarchical approach[4] which spans from the collagen molecules level to the tissue level, including the effect of the bound water at the small length scale and the large porosity at the tissue scale[5]. In particular, a double porosity feature is accounted for, which allows for a large porous matrix with pores of the order of hundreds of microns in a solid phase which exhibits micron-size pores.

The multiscale approach allowed us to determine the mechanical properties of the tissue substitute which were consistent with the available mechanical characterization of the material at the different layers and for different macroscopic porosities.

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