Computational modelling of articular cartilage

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9.1 Introduction

Articular cartilage plays a crucial role in the mechanical function of a diarthrodial joint in which it is located. The mechanical role of articular cartilage is determined not only by its structural compositions and material properties, but also by the contact conditions of the joint. Some background information on the mechanical structure and function of articular cartilage is briefly introduced in this section, followed by a discussion of key issues in cartilage mechanical modelling.

9.1.1 Constituents and properties of articular cartilage

Articular cartilage is a soft connective tissue mostly found in diarthrodial joints. It is also called hyaline cartilage because of its glass-like appearance. The other two types of cartilages are elastic cartilage and fibrocartilage; both contain elastin fibers that are absent in articular cartilage. All cartilage consists of a porous extracellular matrix saturated with a fluid. The extracellular matrix is necessarily composed of proteoglycans and collagen fibers. The elastic cartilage possesses higher amounts of elastin fibers, whereas fibrocartilage contains more collagen fibers, which are stiffer than elastin fibers. Articular cartilage consists of fewer collagen fibers and more proteoglycans as compared to fibrocartilage. Articular cartilage absorbs fluid into its porous matrix due to the negatively charged proteoglycans. The only cells in articular cartilage are chondrocytes, which are surrounded by the pericellular matrix. Articular cartilage is avascular in nature, that is, there is no blood supply in the tissue, which limits the cartilage capabilities in self-repairing when damaged. The mechanical loading that the cells experience largely determines their activity in production or degradation of extracellular matrix.

Articular cartilage is highly inhomogeneous and anisotropic (Fig. 9.1). First, the mechanical properties vary along the tissue depth, often characterized by three zones, superficial, middle, and deep zones (Kempson et al., 1973; Muehleman et al., 2004; Schenk et al., 1986). The depth of the superficial zone is reported to be 10%–20% of the total thickness of the tissue; the collagen fibers are arranged tangentially to the articular surface in this zone. The middle zone usually occupies 40%–60% of the tissue thickness with randomly oriented collagen fibers. The deep zone is adjacent to the

Computational Modelling of Biomechanics and Biotribology in the Musculoskeletal System
https://doi.org/10.1016/B978-0-12-819531-4.00009-2