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Abstracts

Swelling pressure and compressive behavior of cartilage polymers

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The main macromolecular components of cartilage extracellular matrix are proteoglycans (PGs) and collagens, which provide the biomechanical properties of the tissue. The PGs are negatively charged and exhibit a high osmotic swelling pressure that is essential to the compressive resistance of cartilage. The collagen network immobilizes the proteoglycan assemblies and provides resistance of cartilage to tension. The dominant PG in cartilage is the bottlebrush shaped aggrecan, which forms large aggregates with hyaluronic acid (HA) and link protein. The aggrecan bottlebrushes contain long sulfated glycosaminoglycan (GAG) chains, primarily chondroitin sulfate (CS) and keratan sulfate (KS) chains. CS and KS provide the fixed charged density to the tissue due to their sulfate and carboxyl groups. The electrostatic repulsive forces arising from the high charge density of the negatively charged GAG molecules favor chain extension and generate highly swollen gel-like structures. The microgel nature of aggrecan/HA assemblies defines important biomechanical properties of cartilage.

We report a systematic experimental study aimed to determine the interactions between the main macromolecular constituents of cartilage extracellular matrix. The static properties were determined from scattering (light, neutron and X-ray) measurements and macroscopic osmotic swelling pressure observations. The dynamic behavior was investigated by dynamic light scattering, neutron spin-echo and rheological measurements. A unified framework was developed to evaluate the experimental results obtained by these complementary techniques probing the structure and dynamics over a wide range of length and time scales.

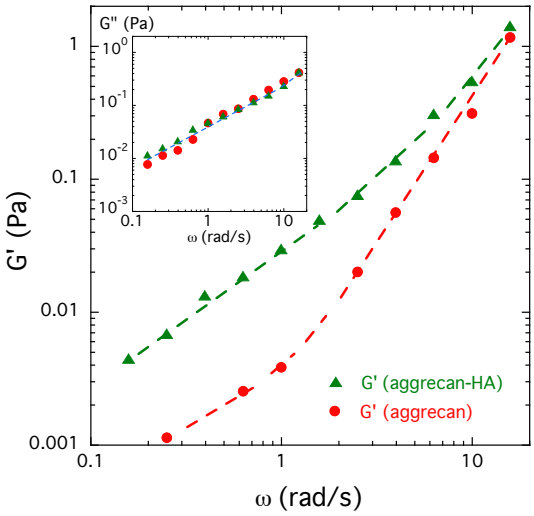

Figure 1. Frequency dependence of the storage modulus G' in aggrecan and aggrecan-HA solutions (polymer concentration: 5 mg/cm^3). Inset: loss modulus G'' as a function of the frequency, ω.