Quantitative Magnetic Resonance Imaging of the Articular Cartilage of the Knee Joint

Richard Kijowski, MD*, Rajeev Chaudhary, BS

KEYWORDS

• Cartilage • Magnetic resonance imaging • Quantitative • Proteoglycan • Collagen • Review

KEY POINTS

- Quantitative magnetic resonance imaging can be used to noninvasively assess the composition and ultrastructure of articular cartilage.
- Quantitative magnetic resonance imaging can be used in clinical practice to detect early cartilage degeneration.
- Quantitative magnetic resonance imaging can be used in osteoarthritis research studies to monitor disease-related and treatment-related changes in articular cartilage over time.

INTRODUCTION

Osteoarthritis is one of the most common chronic medical conditions and is second only to cardiovascular disease as the leading cause of disability in the United States.[1–5] Osteoarthritis may be caused by idiopathic or posttraumatic degeneration of articular cartilage. Characteristic changes in articular cartilage occur during the disease process including a decrease in the proteoglycan content and disruption of the highly organized collagen fiber network.[6–11] Identifying the sequence of events that occur during cartilage degeneration is essential for better understanding of the pathogenesis of osteoarthritis and developing improved treatment options. Quantitative magnetic resonance (MR) imaging provides a noninvasive method to assess cartilage composition and ultrastructure. This article reviews the role of quantitative MR imaging for evaluating the articular cartilage of the knee joint, which is one of the joints most commonly affected by osteoarthritis.

CARTILAGE COMPOSITION AND FUNCTION

Articular cartilage is composed of chondrocytes, which compose approximately 4% of the net weight of the tissue, and an abundant extracellular matrix. The extracellular matrix of cartilage consists primarily of water, composing between 65% and 85% of its net weight, and lower concentrations of proteoglycan and type II collagen.[12,13] Proteoglycan composes 3% to 10% of the net weight of cartilage and allows the tissue to withstand high compressive forces during joint loading. Collagen composes 15% to 20% of the net weight of cartilage and is responsible for the tensile strength of the tissue.[12,13] Articular cartilage is devoid of lymphatics, blood vessels, and

The authors have no disclosures regarding subject matter or materials discussed in the article.
Department of Radiology, University of Wisconsin School of Medicine and Public Health, 600 Highland Avenue, Madison, WI 53792-3252, USA
* Corresponding author. Department of Radiology, University of Wisconsin School of Medicine and Public Health, Clinical Science Center - E3/311, 600 Highland Avenue, Madison, WI 53792-3252.
E-mail address: rkijowski@uwhealth.org

Magn Reson Imaging Clin N Am 22 (2014) 649–669
http://dx.doi.org/10.1016/j.mric.2014.07.005

nerves, limiting its potential for healing and repair.[13] Thus, preservation of the cartilage macromolecular matrix is vital to joint health.

The macromolecular matrix of articular cartilage is composed of type II collagen organized in a complex 3-dimensional orientation, which provides tensile strength and determines tissue anisotropy.[14] The articular surface is covered by the lamina splendins; dense bundles of collagen fibers lubricated by a proteoglycan called lubricin; and synovial fluid, which allows for low friction load transmission across the joint.[15] The superficial zone of cartilage is composed of collagen fibers and elongated chondrocytes orientated parallel to the articular surface, whereas the middle zone is characterized by a random orientation of collagen fibers intermixed with round chondrocytes. The deep zone of cartilage consists of thick bundles of collagen fibers and elongated chondrocytes oriented perpendicular to the bone-cartilage interface. The radially oriented collagen fibers in the deeper layer of cartilage pass through the calcified zone to attach to subchondral bone (**Fig. 1**).[13]

The major proteoglycan constituent of articular cartilage is aggrecan, which is composed of a core protein with alternating domains of the negatively charged sulfated glycosaminoglycan side chains keratan sulfate and chondroitin sulfate. Aggrecans are assembled into a macromolecular structure of monomers, which are bound to a hyaluronan backbone through a link protein. The core protein of aggrecan consists of 3 globular domains (G1, G2, and G3) and 3 interglobular domains.[16] The G1 domain resides on the N-terminus and interacts with the link protein to attach aggrecan to the hyaluronan backbone, whereas the G3 domain is located at the C-terminus of the glycoprotein. Located between the G2 and G3 domains are the attachment domains, which link the keratan sulfate and chondroitin sulfate side chains to the core protein (**Fig. 2**).[17]

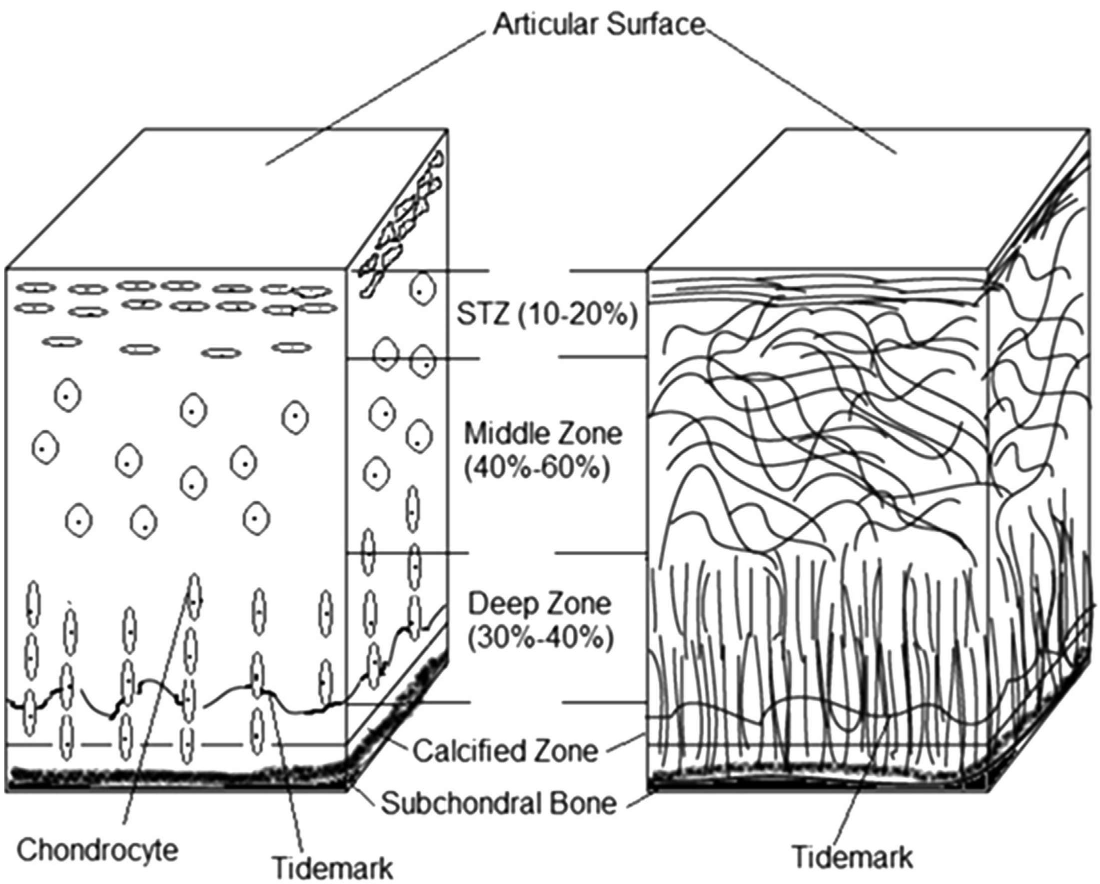

Fig. 1. Articular cartilage divided into its histologic zones. The image depicts the cellular structure and organization as well as the collagen fiber orientation of cartilage from surface to bone. Note the randomness of collagen fibers in the middle zone of cartilage. STZ, superficial zone. (*Adapted from* Xia Y. Averaged and depth-dependent anisotropy of articular cartilage by microscopic imaging. Semin Arthritis Rheum 2008;37(5):317–27.)