ELSEVIER

Operative Techniques in
Orthopaedics

Cartilage Biomechanics and Implications for Treatment of Cartilage Injuries

Alexis C. Dang, MD,[*,†] and Alfred C. Kuo, MD, PhD[*,†]

Orthopaedic surgeons are involved in the care of the entire musculoskeletal system, which encompasses a wide variety of tissues with differing healing potentials. On one side of the spectrum is bone, which is one of the few tissues that can heal without scarring. On the other side of the spectrum is cartilage, which provides structural support and load bearing, but has little healing potential. The structural content and organization of cartilage are essential to its biomechanical functions. Understanding how the unique characteristics of different types of cartilage relate to their functions will help surgeons select the optimal treatments for cartilage injuries.

Oper Tech Orthop 24:288-292 Published by Elsevier Inc.

KEYWORDS meniscus, articular cartilage, fibrocartilage, hyaline cartilage

Introduction

Cartilages are avascular, dense, tough, elastic, fibrous connective tissues that serve multiple roles. Transient cartilages are a major constituent of embryonic skeletons and provide a template for bone formation. Permanent cartilages include elastic cartilage, hyaline cartilage, and fibrocartilage. These tissues represent a spectrum of tissue types, with varying functions and biomechanical properties. Elastic cartilage is found in the earlobe, epiglottis, and larynx. In this review, we focus on hyaline cartilage (such as articular cartilage) and fibrocartilage (such as meniscal cartilage), which play important roles in joints and intervertebral discs. Chondrocytes, the cellular constituent of cartilage, comprise a small proportion of the volume of cartilaginous tissues. The properties of cartilage are determined by the extracellular matrix (ECM) that is synthesized by these cells. The different biomechanical properties of these varied types of cartilage are directly related to their function. Understanding of the unique biomechanical characteristics of cartilages will help to provide insights into the challenges of developing therapies for cartilage repair and regeneration.

Chondrocytes are the building blocks of cartilage and can be broadly defined by their location and appearance within cartilage lacunae. Beyond this physical appearance, chondrocytes synthesize ECM proteins such as proteoglycans and collagens, including collagen type II (hyaline cartilage) and collagen type I (fibrocartilage). We can further differentiate chondrocytes from other cells by reviewing gene-expression profiles of chondrocytes. In 2007, Funari et al performed a genomic scale analysis of human fetal distal femur cartilage compared with 34 noncartilage tissues and found 161 cartilage selective genes. The top genes identified included COL2A1, AGC1, COMP, COL9A3, MMP3, and PRG4.[1]

Fibrocartilage

Fibrocartilage is found in the meniscus, labrum, triangular fibrocartilage complex, acromioclavicular joint, and annulus of the intervertebral disc. In the knee, meniscal tissue reduces the contact pressures on hyaline cartilage. In 1948, Fairbank's[2] depiction of the postmenisectomy knee described the resulting osteoarthritis. This indicated that not only did the meniscus have a protective role on articular cartilage, but also the wear of articular cartilage could be accelerated with a change in the biomechanical properties of the joint. Although the changes in contact pressure were not initially recognized, this finding did advocate for the beneficial role of the meniscus. It was only a few years earlier, in 1942, when McMurray[3] wrote, “A far too common error is shown in the incomplete removal of the injured meniscus.”

The function of the meniscus is dependent upon its semilunar, wedge shape that contours to the femoral condyle, increasing the contact area of the knee articulation and thus

---

*Department of Orthopaedic Surgery, University of California, San Francisco, CA.

†San Francisco Veterans Affairs Medical Center, San Francisco, CA.

Address reprint requests to Alexis C. Dang, MD, San Francisco Veterans Affairs Medical Center, 4150 Clement St, Box 112, San Francisco, CA 94121. E-mail: kuoAC@orthosurg.ucsf.edu

http://dx.doi.org/10.1053/j.oto.2014.07.001
1048-6666/Published by Elsevier Inc.

reducing the contact pressures on the hyaline, articular cartilage. Within the meniscus, collagen fibers are arranged in both the radial and the circumferential directions. These circumferential fibers create hoop stresses that allow the meniscus to resist compression.[4] Complete loss of the medial meniscus increases peak contact pressures by 235% and reduces contact footprint by 75%.[5] Although the role of the meniscus in preserving cartilage in the knee is no longer controversial, it is important to understand the biomechanical role of the meniscus to preserve its function, in the setting of meniscal injury.[6]

Surgical treatments of meniscal tears have concentrated on improvement of short-term symptoms such as pain, catching, and locking. Therefore, debridement leads to trade-offs between preservation of meniscal function and removal of a pain generator. Recent studies have begun to call in question the short-term benefits of arthroscopic treatment of meniscal tears.[7-11] Optimal repair strategies would therefore not only improve short-term function but also preserve the biomechanical properties of the meniscus.

Clearly, preservation of meniscal tissue is a priority for surgeons who are interested in preserving cartilage. Partial meniscectomies have been shown to be superior to complete meniscectomies.[12] Successful repairs of meniscal tears are dependent upon the ability of the meniscus to heal, and the ability of the meniscus to heal is dependent upon its blood supply. In addition, biomechanical integrity of any repair technique will also aid in meniscal healing. The meniscus receives its blood supply peripherally, therefore "red-red" tears, within the vascularized area, are thought to have increased healing potential vs red-white or white-white zone tears[13] (Fig. 1). In 1990, DeHaven and Sebastianelli[14] published results of open meniscal repair, describing that a durable repair could be achieved.

Biomechanical studies of meniscus tears are primarily done with cadaveric samples without consideration of healing. These studies are still important to provide data on the optimal biomechanical environment for meniscal healing. Repairs should provide meniscal stability with knee range of motion. Recently work has centered on the different techniques for meniscal repair, mainly all-inside techniques vs inside-out techniques. In 2002, Rankin et al[15] compared the traditional inside-out vertical and horizontal mattress sutures with the Biofix arrow and the T-fix device. The vertical mattress suture was the strongest to resist failure and displacement, followed by the horizontal mattress suture, T-fix, and Biofix. This study was performed using bovine menisci examining peripheral tears. Muriuki et al, in 2011, observed in a laboratory study of cadaveric knees that radial tears did not significantly change contact pressures or contact area with axial loading at 0°, 30°, 60°, and 90° of flexion. In this study, side-to-side repair of the radial tear did reverse these nonsignificant changes. Unfortunately, this study could not address the healing potential of a side-to-side repair. These data only consider radial tears that do not involve the posterior horn of the meniscus.[16]

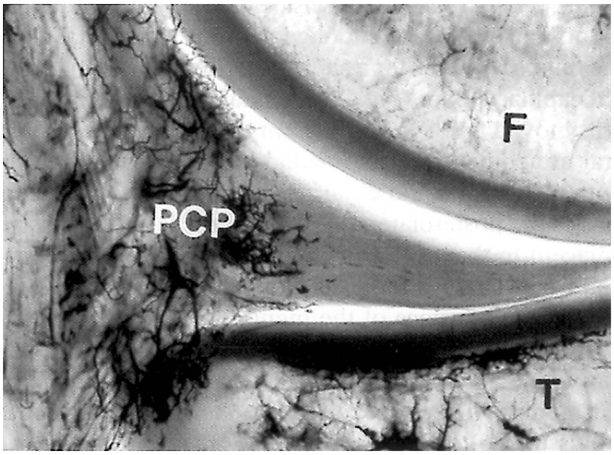

Figure 1 Blood supply of the meniscus. PCP = perimeniscal capillary plexus; F = femur; T = tibia. (Adapted with permission from Greis et al.[43])

In 2009, in a biomechanical study using porcine knees, with a radial tear to the posterior horn of the medial meniscus, Seo et al showed a significant increase in contact pressures and reduction in contact area with a radial tear of the posterior horn of the medial meniscus. A side-to-side repair was shown to restore the biomechanical properties to the joint.[17] The clinical descriptions of side-to-side repairs of radial tears of the posterior horn of the medial meniscus have also been described, although on a second look they have shown unsatisfactory healing.[18] Based on biomechanical data, repair of these tears and subsequent healing should be clinically beneficial. This is similar to the conclusion reached by Padalecki et al in 2014. The reason for this is that the radial posterior horn tears are biomechanically similar to root avulsion injuries or a menisectomized state.[19] Similar findings for posterior horn lateral meniscal tears have also been described by Laprade et al[20] in 2014.

Hyaline Cartilage

Articular cartilage is made up of hyaline cartilage, which has entirely different biomechanical and functional characteristics when compared with fibrocartilage. Hyaline cartilage reduces friction from joint articulation, while also providing resistance to compressive forces. The internal structure of hyaline cartilage helps to optimize this dual function. In a cross-section of hyaline cartilage, the superficial layers consist of collagen fibers oriented parallel to the articular surface, whereas the deeper layers (transitional zone, radial zone, calcified cartilage layer) have collagen fibers oriented perpendicular to the articular surface (Fig. 2). Glycosaminoglycan (GAG) chains make up much of the ECM and serve to hold water. It is this water within the matrix that gives hyaline cartilage's biphasic behavior and viscoelastic properties.[21,22] The proteoglycan and hence ECM properties of these layers are also unique.[23-25]

The chondrocytes in the superficial zone are more closely packed with a different gene-expression profile when compared with the middle zones, where the chondrocytes are in a columnar orientation. A difference in protein production is with the protein lubricin, also known as PRG4, which is thought to reduce surface friction and is currently being studied in a therapeutic application.[26-31]

Download English Version:

https://daneshyari.com/en/article/4078837

Download Persian Version:

https://daneshyari.com/article/4078837

Daneshyari.com