

# MENISCAL PATHOLOGY IN THE DEVELOPMENT AND PROGRESSION OF KNEE OSTEOARTHRITIS RELEVANCE FOR SPORTS MEDICINE

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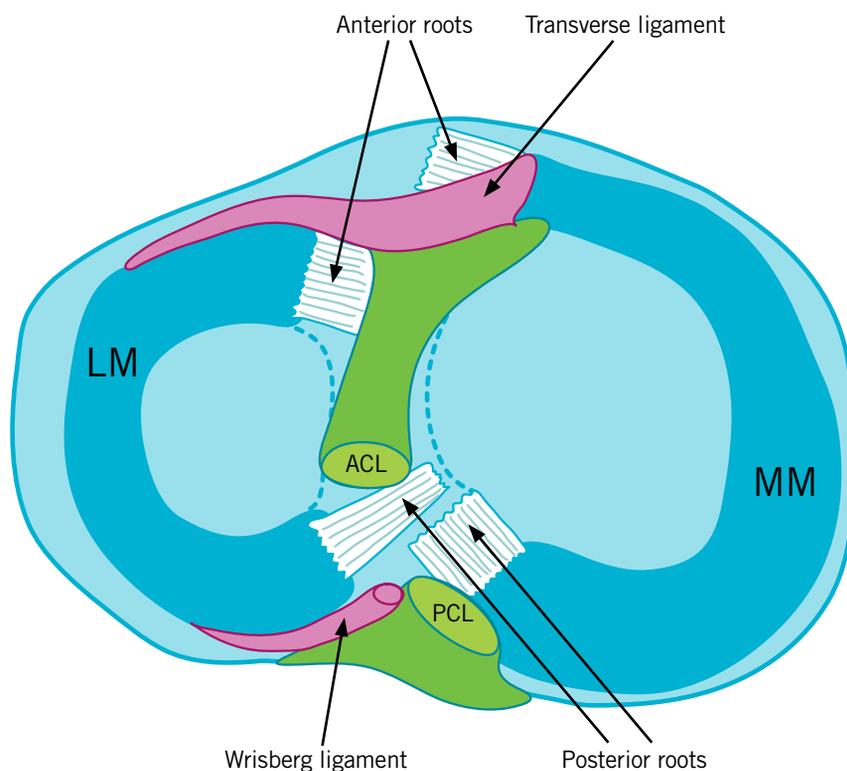
## INTRODUCTION

The menisci are vital to the normal function of the knee joint. Injuries to the menisci are commonly seen in athletes, including players of football, tennis, basketball, baseball, rugby and track and field. Without normal menisci, the knee joint cannot support its full mechanical load, which will lead to pain and limited function in the short-term. In the long run, osteoarthritic changes will develop and worsen over time. Thus, for sports physicians who treat athletes, knowledge of the meniscal anatomy and pathology, as well as its relation to knee osteoarthritis, is important in their daily clinical practice.

## ANATOMY OF THE MENISCI AND MENISCAL ROOTS

The menisci in the knee are two semi-lunar discs made of fibrocartilage. The major components of the meniscus are water, collagen and proteoglycans. They are located between the distal femur and the proximal tibia in the medial and lateral compartments of the knee. The normal meniscus is wedge-shaped in cross section, with the peripheral base attached to the joint capsule. The meniscal surface facing the femur is concave and the tibial surface is flat. The anterior and posterior horns of the meniscus are anchored to the tibia by ligamentous attachments, the

meniscal roots, to the tibial plateau (Figure 1). Medially, the posterior root inserts into the posterior slope of the medial tibial tubercle, while the anterior root of the medial meniscus inserts broadly into the anterior intercondylar crest. Laterally, most of the posterior root inserts into a horizontal part of the posterior intercondylar area, but some fibres attach to the posterior slope of the lateral tubercle. The anterior root of the lateral meniscus inserts into a portion of the anterior intercondylar crest in front of the lateral tibial tubercle and lateral to the anterior cruciate ligament, with which it partially blends. The medial meniscus is firmly attached to the medial collateral



**Figure 1:** Anatomical configuration of the menisci, meniscal roots and ligaments in the right knee. LM=lateral meniscus; MM=medial meniscus, ACL=anterior cruciate ligament, PCL=posterior cruciate ligament.

ligament. In contrast, the lateral meniscus is more mobile because it is separated from the lateral collateral ligament and the joint capsule at the popliteal hiatus.

The outer third has vascular supplies and is called the 'red zone'. If a small tear occurs here, natural healing may occur. The nerve fibres mostly follow the blood vessels, with the two horns of the meniscus being the most richly innervated. The inner two thirds, called the 'white zone', have no vascular or nerve supply.

The most important properties of the collagen-proteoglycan meniscal matrix are its ability to resist tension, compression and shear stress. The menisci distribute mechanical stress over a large area of the articular cartilage of the femur and tibia. When the knee is loaded, the tensile strength of the healthy meniscal matrix counteracts extrusion of the meniscus. Thus, the healthy meniscus mainly responds to load with compression rather than extrusion.

#### MRI OF MENISCI AND MENISCAL ROOTS

MRI enables visualisation of the meniscus and its pathologies non-invasively with high spatial resolution and a high signal-to-noise ratio. For optimum imaging, a dedicated knee coil should be used. Slice thickness

should be set at 3 mm or less. Both sagittal and coronal images are essential and, in addition, axial images can be useful for detection and characterisation of meniscal pathology. Currently, a fat-suppressed intermediate-weighted fast spin-echo sequence with an echo time of about 35 ms and a long repetition time is the preferred choice to achieve the maximum contrast-to-noise ratio. This MRI sequence is also useful for visualising cartilage, subchondral bone, ligaments and joint fluid. The sensitivity and specificity of MRI for detecting meniscal tears are reported to be in the range of 82 to 96%, and use of the 'two-slice touch' rule in bi-dimensional techniques i.e. visualisation of the tear on at least two adjacent slices, has been shown to be highly specific<sup>1</sup>. Detailed reviews of imaging of the meniscus and its pathology using conventional MRI techniques have been published by Niitsu and colleagues<sup>2</sup>.

#### MODERN IMAGING TECHNIQUES FOR EVALUATION OF MENISCUS

Three-dimensional segmentation techniques based on MRI make detailed analysis of meniscal positioning and estimation of meniscal tissue volume possible. These techniques will, hopefully, help to

determine the associations between the components of the menisci and the forces to which it is subject and the pathogenesis of knee osteoarthritis. These techniques supplement the several published semi-quantitative MRI scoring systems that incorporate visual assessment of meniscal morphology and positioning<sup>3</sup>.

Modern MRI techniques using delayed gadolinium-enhanced MRI (dGEMRIC), T1rho and T2-mapping techniques enable visualisation of the physiological status of normal and pathologic menisci<sup>4,5</sup>. Ultrashort echo time-enhanced T2\* mapping can show collagen disorganisation within the meniscus and may aid detection of subclinical meniscal degeneration<sup>6</sup>. These imaging methods can help to understand the relevance of early-stage intrameniscal changes and gain new insights into the disease process well before morphological changes detectable by conventional MRI such as tears of the menisci occur.

#### MENISCAL PATHOLOGY AND ITS IMAGING APPEARANCES

##### *Traumatic meniscal tears*

Acute knee trauma during sports is a major cause of internal injuries of the knee such as damage to the menisci, cartilage,



**Figure 2:** 20-year-old basketball player. a) Coronal intermediate-weighted MRI shows an amputated posterior horn of the medial meniscus (red arrow) and medial collateral ligament tear (black arrow). b) Sagittal intermediate-weighted MRI shows shattered posterior horn of the medial meniscus with a meniscal fragment anteriorly displaced (red arrow) just posterior to the anterior horn. There is also partial thickness loss of the weight-bearing central medial femoral condyle (black arrow).



**Figure 3:** 28-year-old football player with injury 6 months earlier. a) Coronal intermediate-weighted MRI shows avulsion of the posterior root and posterior horn of the lateral meniscus (arrow). b) Sagittal intermediate-weighted MRI confirms the findings in a) and shows that the posterior horn is not lying anteriorly to the anterior horn (red arrow). There is a large focal cartilage defect at the central weight bearing lateral femur with subchondral bone marrow cystic changes (white arrow). There is also a large joint effusion (star).

cruciate and collateral ligaments (Figures 2 and 3). According to a published report, the incidence of acute meniscal tears presented at an emergency department is approximately 70 per 100,000 persons per year<sup>7</sup>. A recent systematic review found that playing football or rugby is a strong risk factor for acute meniscal tear<sup>8</sup>. The same study also showed that waiting more than 12 months between anterior cruciate ligament injury and reconstructive surgery is a strong risk factor for a subsequent medial meniscal tear but not for a lateral meniscal tear<sup>8</sup>. On impact, the meniscus typically splits vertically, in line with the circumferentially oriented collagen fibres, leading to a longitudinal tear. The torn part may dislocate and become wedged between the femoral condyles causing a 'locked knee' – a condition that requires arthroscopic surgical treatment such as a partial meniscectomy. Complete radial

tears or tears of the meniscal roots are very important because they may lead to substantial meniscal extrusion, which in turn results in a loss of normal meniscal function as well as progression of cartilage damage within the tibiofemoral joint<sup>9</sup>.

#### *Degenerative meniscal tears*

Meniscal tears can also occur as an age-related degenerative process in persons without a known history of knee trauma (Figure 4). A population-based epidemiological study in Framingham, Massachusetts, USA, showed that the prevalence of MRI-detected meniscal tears increased with age, ranging from 16% in the knees in 50 to 59-year-old women to over 50% in the knees of men aged 70 to 90 years regardless of the presence of radiographic osteoarthritis<sup>10</sup>. In addition, in this population-based sample, 10% had partial destruction or a complete

absence of normal meniscal tissue, which is not classified as a meniscal tear but is commonly associated with radiographic evidence of osteoarthritis. Interestingly, MRI-detected meniscal damage was found in 24% of persons who had no radiographic osteoarthritis, with or without knee pain<sup>11</sup>. Such studies demonstrate the high prevalence of meniscal damage in the general population, and also the fact that meniscal tears do not necessarily cause pain. Thus, meniscal tears are a common finding, often found incidentally on MRIs of the knee. These types of meniscal tears are considered 'degenerative'. They are typically horizontal cleavage lesions or flap tears of the body or posterior horn of the medial meniscus, and may be associated with varying degrees of meniscal destruction. Risk factors for non-traumatic degenerative meniscal tears include generalised osteoarthritis expressed as the presence

**Figure 4:** 34-year-old football player. Sagittal intermediate-weighted MRI shows degenerative complex horizontal and radial tear of the posterior horn of the medial meniscus. There is also a diffuse partial thickness loss of the weight-bearing central tibial and femoral cartilage.

**Figure 5:** 57-year-old woman with normal posterior root of the right medial meniscus. Coronal STIR MRI shows a continuity of the band-like hypointensity between the posterior horn of the medial meniscus and the tibial plateau (white arrow). There is no meniscal tear or extrusion. Similarly, the posterior root of the lateral meniscus is also intact (red arrow).



**Figure 6:** 33-year-old baseball player. Coronal intermediate-weighted MRI demonstrates posterior root tear (arrow) of the medial meniscus associated with meniscal extrusion.

of multiple bony enlargements of finger joints, varus alignment of the lower limbs and a history of an occupation that involves kneeling such as carpet laying.

#### *Meniscal root tears*

The meniscal roots are readily identifiable on MRI (Figures 5 and 6). Tears of the meniscal roots are distinctly different than tears of the anterior or posterior horn of the meniscus. Isolated meniscal root tears can occur with no tearing of the meniscus itself. Tears of the medial posterior meniscal root are not unusual in daily clinical practice, while tears of the lateral posterior root are less common and tears of the anterior meniscal root are extremely rare<sup>9</sup>. When the meniscal root tears, the meniscus is no longer held within the joint, possibly resulting in meniscal extrusion, which will

render the meniscus incapable of its normal function as a buffer of the load on the tibiofemoral joint. Thus, meniscal root tears seem to have an effect that is equivalent to a 'pseudomeniscectomy'.

#### *Meniscal extrusion*

Tears of the menisci as well as of the meniscal roots are often associated with some degree of meniscal extrusion i.e. radial displacement of the meniscus outside the joint margin (Figure 5). Extrusion of the body of the meniscus occurs commonly in osteoarthritic knees. Meniscal extrusion and the resultant reduced coverage of the tibial surface can lead to tibiofemoral cartilage loss, as well as bone marrow lesions. It is important to note that meniscal extrusion contributes to the tibiofemoral joint space narrowing seen on conventional

radiography. Thus, extrusion is an integral part of knee osteoarthritis as the disease is often clinically defined by the combination of symptoms and radiographic evidence of joint space narrowing.

#### **MENISCAL PATHOLOGY AS A RISK FACTOR FOR DEVELOPMENT AND PROGRESSION OF KNEE OSTEOARTHRITIS**

Meniscal tears and extrusion, as well as meniscal root tears, are key factors in the early-stage development of knee osteoarthritis.

#### *Pathologic pathway leading to knee osteoarthritis*

Knee osteoarthritis is often a result of increased mechanical loading and the pathologic response of joint tissues to excessive mechanical stress. Knee



## **An ongoing trial on patients 45 years or older reported no statistically significant benefit from partial meniscectomy compared to physical therapy in the short-term**



malalignment, high body mass index and occupational hazards are factors that contribute to chronic overloading of the knee joint. Such overloading, together with degenerative changes in the meniscal matrix that may be related to early stage osteoarthritis can result in meniscal fatigue, rupture and extrusion. If the meniscus loses its critical function in the knee joint, the effects of the changes in the patterns of mechanical loading on joint cartilage can result in cartilage loss, bone alterations including trabecular bone changes, increased bone mineral density, development of subchondral bone marrow oedema-like lesions and worsening malalignment.

This pathologic pathway leading to osteoarthritis can also result from injuries of the knee, in which normal meniscal function is lost in a previously healthy knee. Therefore, preservation of as much functional meniscal tissue as possible is crucial. The meniscal tissue may still contribute substantially to buffering of the mechanical load to the knee, and preservation is important not only when treating traumatic tears but also in patients with horizontal tears and/or intrasubstance signal changes on MRI. Cartilage loss occurs mainly in the vicinity of the damage to the meniscus suggesting a cause and effect relationship between the meniscal damage and structural disease progression.

### ***Meniscal pathologies and knee symptoms***

The association between meniscal tears and knee symptoms is complex in all knees, with or without osteoarthritis.

Certain types of meniscal tears may cause more pain and discomfort (e.g. catching or locking symptoms) and/or functional limitation than others. For example, a 'bucket-handle' tear can cause locking of the knee and may require surgical treatment such as arthroscopic partial meniscectomy. However, sports physicians should be aware that a meniscal tear itself may not be the direct cause of symptoms in some patients with knee pain. Just because a tear is detected by knee MRI or arthroscopy, surgical resection of the torn meniscal tissue will not necessarily be the immediate solution for the patient's pain or provide a long-term solution. Other pathologic features of osteoarthritis such as joint effusion, synovitis and bone marrow oedema-like lesions can also cause pain. This is particularly likely in patients with pre-existing knee osteoarthritis. There is a speculation that meniscal extrusion may cause stretching and/or irritation of the synovial capsule, and consequent knee pain, but exactly how meniscal extrusion contributes to knee pain is unknown.

### ***Is surgical therapy more beneficial than conservative management?***

#### **Partial meniscectomy vs physical therapy**

Nowadays, partial meniscectomy is a common surgical procedure to treat patients with meniscal damage that causes mechanical interference with movement of the knee joint. However, there is little scientific evidence to show that arthroscopic meniscectomy provides more benefit than non-surgical management in the treatment of degenerative meniscal lesions in middle-

aged and elderly patients with knee pain. An ongoing multi-centre randomised clinical trial involving symptomatic patients 45 years of age or older with a meniscal tear and evidence of mild-to-moderate osteoarthritis on imaging has reported no statistically significant benefit from partial meniscectomy as compared to physical therapy in the short-term (6 months)<sup>12</sup>. Currently, there are ongoing randomised trials in both Europe and USA that will hopefully cast further light on how to determine which patients will benefit from surgical intervention for a degenerative meniscal tear in the absence of radiographic osteoarthritis and which will benefit from physical therapy alone.

#### **Surgical repair and replacement**

Currently, meniscal repair surgery is commonly used to treat younger patients when a traumatic tear is located within or close to the vascularised zone of the meniscus. In contrast, meniscal lesions in the middle-aged and elderly are typically located away from the vascularised zone and consequently are not amenable to repair. Also, rehabilitation after surgical repair tends to be more extensive than after meniscectomy, and the long-term outcome of meniscal repair compared with partial meniscectomy is unclear.

Meniscal lesions found in the avascular inner region, which functions in a highly demanding mechanical environment, are considered to be a significant challenge for surgery. Meniscal replacement using transplants or scaffolds has been attempted, but there is a paucity of evidence

documenting the long-term outcome of repair surgery in the inner avascular region. Nevertheless, meniscal replacement may have potential in selected patients, particularly those with an otherwise healthy knee in which a large portion of the meniscus cannot be saved due to the extent of damage, as is often the case in severe first time knee injuries in athletes. Meniscus-like tissue ingrowth may occur in polyurethane scaffolds implanted to treat partial meniscal lesions. However, a considerable amount of time will be required to learn more about the value of implants for them to become more widely used clinically. We should keep in mind that

the prevalence of meniscal damage is high in the general population<sup>10,11</sup>. Thus, surgical techniques such as meniscal replacement are only likely to be indicated in highly selected patients.

#### *Clinical challenges concerning management of meniscal tears*

The main clinical challenge we face currently is understanding the long-term efficacy of arthroscopic partial meniscectomy vs conservative management of patients with degenerative meniscal tears and knee pain. We need to know if the long-term prognosis differs with respect to clinically relevant outcomes and

to the risk for developing knee osteoarthritis later on. We also need to better understand indications for surgical therapy and the implications of healthcare economics. In younger patients, surgical techniques of meniscal repair or replacement appear promising, but again we need more evidence for the long-term outcome.

#### CONCLUSIONS

Sports physicians treating athletes regularly encounter patients with acute knee trauma, including tears of the menisci and the meniscal roots. These structures are highly important for maintaining a healthy knee joint. When a meniscus or a meniscal root is torn by a knee injury or degenerative processes, the risk of developing knee osteoarthritis later in life increases. Meniscal damage and extrusion often have a key role in the morphological progression of the disease. We should keep in mind that most meniscal tears are found in middle-aged and elderly persons without knee pain or history of knee trauma. In fact, knee pain can be caused by other structures or pathophysiological processes within the osteoarthritic joint. In other words, surgical management may not always be required just because that is the structural pathology demonstrated by MRI or arthroscopy. Degenerative meniscal tears, for example, may be conservatively managed with exercise therapy first. However, if traumatic or degenerative tears of the meniscus or meniscal roots are causing symptomatic mechanical interference, surgery should be considered. An extensive meniscal resection may help some patients in the short-term but the long-term risk of developing osteoarthritis needs to be weighed carefully in the decision-making process. Excessive resection during partial meniscectomy may facilitate progression of osteoarthritic changes. Recent development of advanced MRI protocols and image processing techniques for research purposes shows promise for uncovering early-stage changes of meniscal matrix and other associated tissues. Modern MRI techniques, therefore, may help us better understand the pathological mechanism of the onset of osteoarthritis of the knee and to further evaluate surgical techniques of damaged menisci and meniscal roots.



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long-term efficacy..**

