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Patellofemoral Imaging and Analysis

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Imaging of the patellofemoral joint (PFJ) is useful to evaluate for injury and to better understand the relationship between osseous and soft tissue structures. Interpretation of PFJ imaging findings should be used in the context of patient's history and physical examination. X-rays and advanced imaging technology can provide information to confirm diagnosis and to help customize individual treatment plans. This chapter reviews relevant imaging studies utilized in the work-up and treatment of patients with patellofemoral disorders. Oper Tech Sports Med 27:150684 © 2019 Published by Elsevier Inc.

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Patellofemoral joint (PFJ) disorders encompass a wide spectrum of disease. Pathology can arise from trauma, dislocations, overuse, or as a result of chronic maltracking. Certain anatomic abnormalities alter PFJ forces and increase risk for PF dislocation and/or lead to progressive PF chondrosis.¹ Clinically, these anatomic and biomechanical abnormalities may manifest as PF pain, instability, or a combination of these findings. Imaging of the PFJ is utilized to evaluate injured structures, variations in anatomy (ie, trochlear dysplasia), and relationships between osseous and soft tissue structures that contribute to aberrant PF mechanics.^{2,3} However, it is important to note that not all anatomic variants are pathologic, as is the case in findings such as asymptomatic bipartite patella. As such, imaging findings should always be correlated clinically with the patient's physical exam and considered in context of their history and symptoms. Successful treatment of PF disorders requires a thorough understanding of the patient's anatomy and biomechanics in order to recognize and correct common patterns of pathology. A comprehensive treatment plan must take into account both the biology and biomechanics to optimize PF tracking.⁴ In order to do so, appropriate knee imaging must be obtained and applied in the context of individual patient evaluation. This chapter will review

relevant imaging studies utilized in the work-up and treatment of patients with PF disorders (Table 1).

Radiography

Following a detailed patient history and physical examination, a standard radiographic x-ray series should be obtained for any patient presenting with PF symptoms. This series should include bilateral weight-bearing anteroposterior and flexed posteroanterior (Rosenberg) views, lateral x-rays of the affected limb, and bilateral low flexion axial views (such as a Merchant view).^{5,6} Typically, the Anterior-Posterior (AP) view is useful for screening out femoral anteversion, as the exam can appear as an AP of the tibia and oblique view of the femur. It is important to obtain a proper lateral view in which the posterior femoral condyles are overlapped, as rotation of the film can obscure accurate interpretation of trochlear dysplasia, patella height, and tilt. Weight bearing mechanical axis views should be included when there is concern for coronal plane tibiofemoral malalignment.⁷ This can be utilized to evaluate for valgus as well as measuring this source of such deformities, such as lateral femoral condyle hypoplasia.

Advanced Imaging (CT and MRI)

Advanced imaging, in the form of Computed Tomography (CT) or Magnetic Resonance Imaging (MRI), provides a more comprehensive analysis of the patient's anatomy. This is

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Table 1 Clinical Applications of Different Imaging Modalities

Imaging Modality	Clinical Assessment
X-ray	Femoral anteversion, trochlear dysplasia, patella height, patellar tilt, and tibiofemoral malalignment
MRI	Hemarthrosis, cartilage defects, osteochondral loose bodies, trochlear dysplasia, TT-TG, TT-PCL, ligamentous injury, meniscal pathology, lateral patellar tilt, tears of the medial patellofemoral ligament, and bone marrow edema
CT	TT-TG, TT-PCL, trochlear dysplasia, lateral patellar tilt, and tears of the medial patellofemoral

especially true when analyzing the anatomy in cross-section. Such imaging modalities aid in both diagnosis and preoperative planning. An MRI should be obtained after any injury causing an acute hemarthrosis and can be especially helpful in the evaluation of any cartilage defects, osteochondral loose bodies, and to fully characterize the presence of trochlear dysplasia. In addition, MRI can also provide detailed views of the menisci and ligamentous structures, allowing full view of any surrounding soft tissue injuries. There are several findings noted in the literature to be commonly present in patients with PF instability. These include trochlear dysplasia, elevated tibia tubercle–trochlear groove [TT-TG] or TT= posterior cruciate ligament [PCL] distance, tears of the medial PF ligament, patella alta, and lateral patellar tilt.⁸⁻¹² Both CT and MRI are useful in the assessment of these findings.

Techniques developed for MRI have replaced a number of measurements originally obtained on CT scan, rendering the need for both studies unnecessary in many scenarios.¹⁰ However, in the setting of complex torsional abnormalities that may affect the femur or tibia, CT version studies remain the imaging modalities of choice. Some advantages provided by CT include the capture of bony detail in exquisite resolution, as well as faster and less physically confining as MRI. These advantages allow for kinematic imaging where CT scans can be repeated at various degrees of flexion in order to evaluate PF tracking. Repeat CT scans are obtained at 0°, 30°, 45°, 60° in order to evaluate patellar engagement of the trochlea, although this is not routinely performed. At the same time scout images of the hip and ankle can be obtained on MRI and obviate the need for the radiation associated with CT scans. Overall, CT is most often utilized in evaluation of subchondral bone, union of fractures or osteotomy sites or to obtain 3D imaging in patients with contraindications to MRI.¹³⁻¹⁵ CT arthrogram may also be useful to evaluate the stability of OCD lesions.

By comparison, MRI offers far superior definition of cartilage and soft tissue, more straight forward evaluation of patellar and trochlear shape, characterizes osseous bone marrow lesion patterns, osteochondral fragment avulsions, and injury to soft tissue structures such as the medial PF ligament (MPFL) which are present following patellar dislocations or

acute trauma.^{12,16,17} Various MRI pulse sequences can selectively define morphologic and ultrastructural changes. These ultrastructural changes represent a shift in the major elements of cartilage (water, proteoglycan, and collagen) and are reflective of cartilage health and viability. For example, proton density-weighted fast spin echo sequences demonstrate high in-plane resolution, as well as high sensitivity (87%), specificity (94%), and accuracy (92%) for detection of chondral lesions in the knee joint.¹⁸ Newer MRI techniques using T1 rho, T2 mapping, or delayed Gadolinium Enhanced Magnetic Resonance Imaging of Cartilage (dGEMRIC) can evaluate cartilage ultrastructure.¹⁹

T1 rho imaging is very sensitive regarding early osteoarthritis and maps proteoglycan loss from the extracellular matrix of cartilage, which is directly related to its health and vitality.^{17,20-24} Individuals with osteoarthritis demonstrate elevated cartilage T1rho values compared with healthy patients.²⁵ T2 mapping assesses the organization of collagen in cartilage and helps to identify early degeneration, represented as high signal areas relative to normal cartilage.²⁶ In normal cartilage, collagen adjacent to subchondral bone shows lower signal intensity while the middle transitional zone demonstrates more randomly-ordered collagen and generates higher signal intensity. This stratification is lost in abnormal cartilage and collagen arrangement is disordered, reflected by higher T2 values.²⁷ dGEMRIC is a quantitative method for estimating glycosaminoglycan distribution in cartilage. MRI contrast for this method contains a negatively charged Gd²⁺-containing chelate, which diffuses more readily into diseased cartilage with lower glycosaminoglycan content highlighting diseased areas.²⁸

Analysis and Interpretation

Plain film radiographs play an important role in the initial evaluation of PF symptoms. These images allow for the detection of abnormal anatomical variations, as well as the presence of PF arthritis.²⁹ Findings often include abnormal patellar height, patellar tilt, patellar subluxation, lateralization of the tibial tuberosity, and trochlear dysplasia.²

Sagittal Alignment

Patella alta results from proximal positioning of the patella relative to the trochlea and/or an elongated patellar tendon, requiring a higher flexion angle for the patella to engage in the trochlear groove. This produces a larger flexion-extension arc along which the patella is not contained, predisposing the individual to abnormal patellar translation, subluxation, or dislocation.^{30,31} By contrast, patella baja results in elevated joint reactive forces between the patella and trochlea, contributing to limited motion, chondromalacia, development of PF pain syndromes, and accelerated onset of PF arthritis.^{32,33} The standard lateral radiograph is the preferred evaluation of patellar height, and multiple methods have been described for evaluation, including the Caton-Deschamps index, Insall-Salvati ratio, modified Insall-Salvati ratio, Blackburne-Peel

index, Blemensaat line, the Bernageau index, and the Bierdert-Albrecht index.^{31,32,34-43} The Caton-Deschamps measurement is preferred because it remains accurate regardless of the degree of knee flexion.³⁴ In addition, the Caton-Deschamps index and the Blackburne-Peel index both reference the articular length of the patella relative to the proximal tibia and can be made on radiographs or MRI. Thus, these measures of patellar height will change if a patient has undergone a distalizing procedure of the tibial tubercle. However, the Insall-Salvati reference lengths which do not change following the same distalization procedures, and therefore will remain the same.⁴⁴ The Caton-Deschamps index is measured by dividing 2 lengths: (1) The distance between the most distal aspect of the articular surface of the patella and the superior, anterior angle of the tibia, and (2) the length of the articular surface of the patella. Resultant values of greater than 1.2 are associated with patella alta, while values less than 0.6 are diagnostic of patella baja⁴⁴ (Fig. 1).

Axial Alignment

Axial malalignment in the setting of PF instability is an exceedingly important concept in the clinical evaluation of anterior knee pain and/or patellar instability. Radiographic measurement of the quadriceps angle, or Q angle, first described by Brattstör in 1970, is obtained by the resultant angle of 2 lines, one drawn from the ipsilateral anterior superior iliac spine to the center of the patella, and a second line from the center of the patella to the tibial tubercle.⁴⁵ Average Q angles typically reported are 14° in men and 17° in women.⁴⁶ Knees with Q angles greater than 20° result in elevated lateral displacement forces on the patella and increased patella contact pressures, resulting in higher risk of patellar instability and anterior knee pain.⁴⁷ The Q angle was utilized frequently until it was questioned for lack of inter-rater reliability due to patient positioning, muscle contraction, or difficulty identifying landmarks.^{48,49} Additionally, multiple factors contribute to increased Q angles, including genu valgum, increased femoral anteversion, laterally-positioned tibial tuberosity, and external tibial torsion, and the reliability and validity of the Q angle are controversial.⁵⁰⁻⁵² At present, cross-sectional imaging is the gold standard for evaluation of the path taken by the

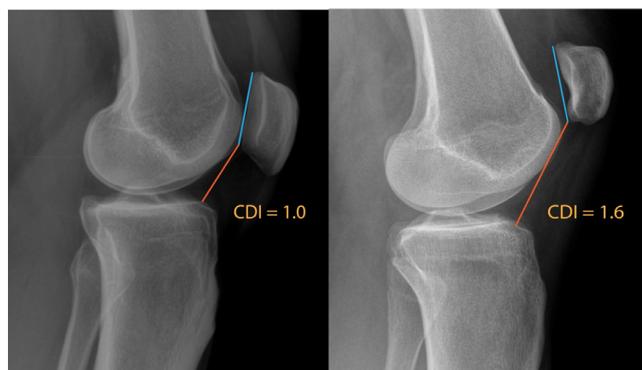


Figure 1 Caton-Deschamps Index (CDI) at a normal (CDI = 1.0) and patella alta (CDI = 1.6).

extensor mechanism, leading to the development of 2 measurements of alignment: the TT-TG and TT-PCL.

TT-TG

The TT-TG distance is a measure of the path taken by the patella in the axial plane and was originally described on axial radiographs, but is now routinely measured on CT and MRI.^{37,53,54} This distance is calculated by superimposing 2 axial CT or MRI slices: one through the deepest aspect of the trochlea, and the other through the center of the most proximal aspect of the tibial tuberosity, with the distance between these points measured in parallel with the posterior condylar line.^{55,56} This measurement aims to characterize the medial to lateral offset applied to the patella between the trochlear groove and the patella's fixation distally to the tuberosity (Fig. 2).

Normal TT-TG values range from 9 to 16 mm on CT scan and 9 to 13 mm on MRI, with values greater than 15 mm being associated with increased risk of patellar instability.^{10,11,53,54,57,58} A measurement of >20 mm represents an excessive lateral position of the tuberosity and is associated with increased incidence of patellar instability.⁵⁹ It is worth noting, TT-TG has high interobserver reliability but measurements tends to differ on the same patient depending on the imaging modality used (CT vs MRI) as well as the degree of knee flexion utilized.^{10,58,60,61}

Severity of an abnormal TT-TG should be taken into consideration when evaluating PF chondral wear and location, presence of a J sign on physical examination, and trochlear dysplasia. Some authors recommend individualizing the absolute value of TT-TG to the patient's size using a ratio, while some surgeons use an anecdotal cutoff of 15–20 mm, beyond which the malalignment is considered pathologic and possibly worthy of intervention.⁶²⁻⁶⁴

TT-PCL

Recently studies confirm that the screw-home mechanism as well as variables affecting knee flexion (joint effusion, MRI coil size, etc) can affect the TT-TG distance relative to knee position.⁶⁵ The screw-home mechanism includes a roll back feature and subsequent internal rotation of the tibia as it moves through the first 30° of knee flexion, thus becoming a variable during TT-TG measurement.^{60,61} Further, TT-TG can be altered by trochlear morphology. Because of these reasons, the TT-PCL distance has gained popularity.³⁷

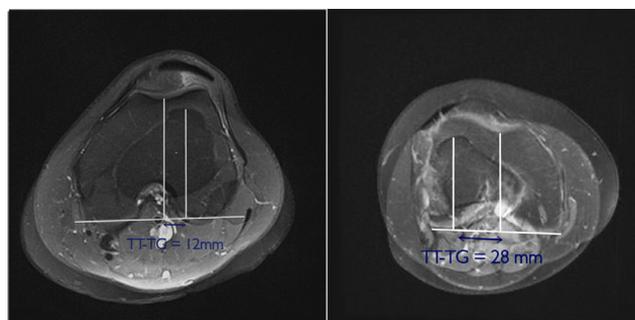


Figure 2 MRI TT-TG at normal (TT-TG = 12 mm) and abnormal (TT-TG = 28 mm) values.

Originally described by Seitlinger, it is the distance between the TT and medial border of the posterior cruciate ligament.^{8,37} The tibial tubercle site is measured from the center of the patellar tendon attachment on the TT and the PCL site as well as the trajectory of measurement is found by using 2 axial images—one with the best view of the medial border of the PCL's attachment site on the tibia, and the other to give the trajectory of the measurement, parallel to the dorsal tibial condylar line⁸ (Fig. 3). Proponents of TT-PCL note that keeping all reference points on the tibia eliminates the variable of knee flexion, focusing purely on lateralization of the TT.⁹ Mean TT-PCL distance is 11.9 ± 4.67 mm, with more than 20 mm considered pathologic.^{8,66,67}

Two studies compared the reliability of TT-TG distance to that of TT-PCL, and both found excellent TT-TG inter-rater reliability, but only moderate for TT-PCL, while another study reported only fair inter-rater reliability for both.^{8,9,68} TT-PCL has not been found to reliably differentiate between patients with and without patellar instability and was outperformed by TT-TG in these studies.^{62,68,69}

Current literature remains in favor of the TT-TG measurement for evaluation of PF axial alignment. While rotation is involved in early knee flexion, the inclusion of points both above and below the tibiofemoral joint lends an important, dynamic component to understanding the path taken by the extensor mechanism. The TT-TG distance is superior to TT-PCL measurement in differentiating those with PF instability from stable counterparts. There are some varying methods for TT-TG assessment, however, TT-TG measurement has been found reliable and not statistically different whether measured proximally or distally along even dysplastic trochlea and that measurement technique most reproducible for the examiner should be used.⁶⁸

Coronal Alignment

Valgus malalignment of the tibiofemoral joint is much less common than varus, although the exact prevalence of genu valgum is not known.⁷⁰ Genu valgum typically originates from a hypoplastic lateral femoral condyle, yielding excessive valgus at the distal femur. The average distal femoral angle is between 7° and 9° of valgus while the proximal tibia is in typically from neutral to 3° of varus. Collectively, these angles contribute to a normal tibiofemoral angle of roughly 5° - 7° of valgus which with the mechanical axis passing

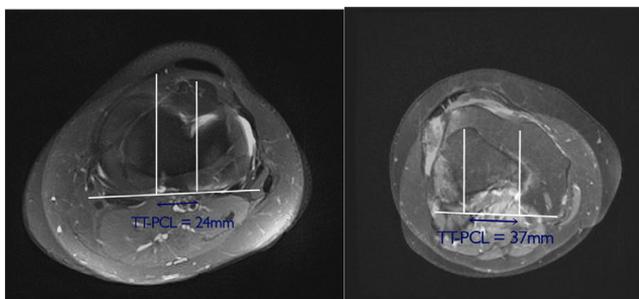


Figure 3 MRI TT-PCL at normal (TT-PCL = 24 mm) and abnormal (TT-PCL = 37 mm) values.

through the center of the knee.⁷¹ In patients with valgus malalignment the mechanical axis passes through the lateral compartment, leading to unequal force distribution and joint contact pressures, thereby causing accelerated lateral (tibiofemoral) compartment degradation. Not only is the lateral compartment affected, but valgus malalignment also alters PF tracking and PF contact pressures and may play a role in the development of PF pain, chondral lesions, and/or instability⁷² (Fig. 4).

Patellar Tilt

PF tilt is the static relationship between the patella and trochlea at a given flexion angle. Patellar tilt is dependent on both bony and soft tissue anatomic restraints and may be measured by use of radiographs, CT, or MRI.^{73,74} Two primary methods exist for assessment of patellar alignment and tilt on standardized axial radiographs or axial advanced imaging

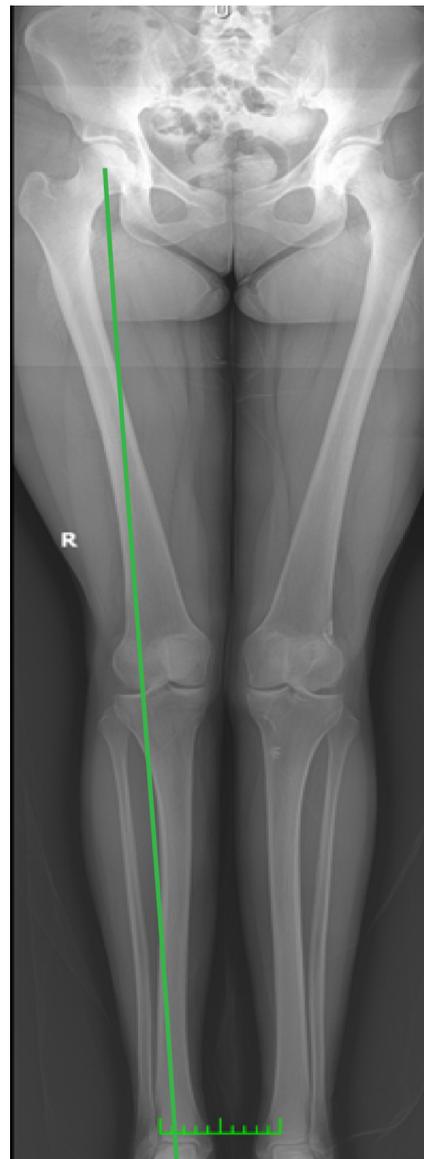


Figure 4 Valgus malalignment on mechanical axis view.

studies—(1) Draw 2 parallel lines, one along the lateral patellar facet and the other along the anterior condylar margins, assessing visually for tilt, or (2) measure the angle between a line drawn parallel to the posterior femoral condyles and another drawn from the median ridge through the edge of the lateral patellar facet. Normal patellar tilt is considered 2° , whereas $>5^\circ$ is considered abnormal^{4,75,76} (Fig. 5).

Trochlear Dysplasia

Central tracking within a normal TG in the absence of abnormal patellar tilt are required for normal PF mechanics, joint reactive forces, and motion.⁷⁷ It has been clearly documented that patients with recurrent PF instability have a high incidence of trochlear dysplasia and that trochlear dysplasia is considered a major anatomic risk factor for patellar instability.⁷⁸⁻⁸⁰ Trochlear dysplasia is also a risk factor for patellofemoral arthritis. Imaging features of trochlear dysplasia are found in more than 85% of patients with patellar dislocation.⁸¹ Patients with trochlear dysplasia have trochlear grooves which are significantly more shallow than normal, creating a loss of bony restraint of the patella provided by the groove, predisposed to patellar instability.⁸² Trochlear dysplasia can be evaluated on lateral and axial radiographs, but more easily on cross-sectional advanced imaging. The depth of a normal TG is 5.2 mm, with the lateral femoral condyle being 3.4 mm higher than the medial femoral condyle in the axial plane.⁴ On perfect lateral radiographic views, a trochlear depth of <5 mm suggests a risk of patellar instability.⁸³ Lateral radiographic views can be used to assess for Dejour A – D types of trochlear dysplasia by assessing for the crossing sign, a supratrochlear spur, and the double contour sign. On axial radiographs, a sulcus angle of 145° or greater also indicates a dysplastic trochlea.⁵³

The Dejour classification of trochlear dysplasia, commonly referenced, is actually 2 slightly different classification schemes developed by 2 different French orthopedic surgeons, one by Henri Dejour and the later by his son David Henri Dejour.^{53,84} The Henri Dejour classification separates trochlear dysplasia into types I, II, and III, but may not accurately gauge the severity of trochlear dysplasia and has extremely poor reproducibility. It has been largely replaced by the more modern Dejour A-D classification (Fig. 6). Both

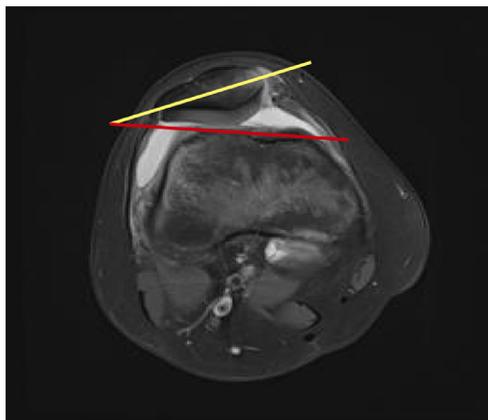


Figure 5 Axial MRI measuring patella tilt.

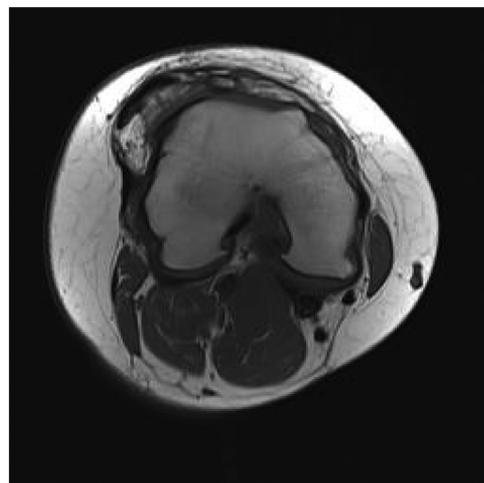


Figure 6. High grade trochlear dysplasia.

methods use plain radiographs, which may underestimate the severity of dysplasia compared with axial MRI. Minimal variations in rotation on lateral radiograph can grossly change characterization of trochlear dysplasia and contribute to inconsistencies and only fair inter- and intraobserver reliability in assigning the Dejour classification.^{84,85} However, the Dejour classification remains the most commonly used radiographic means of TD evaluation, and prevailing views are that severe trochlear dysplasia is defined by Dejour types B to D. In Dejour type A, a crossing sign alone is present on the lateral radiograph. In Dejour B, a crossing sign is seen, along with the presence of a supratrochlear spur. In Dejour C, the crossing sign is present, and a hypoplastic medial condyle is also seen, causing a double-contour sign to be seen. Finally, Dejour type D includes all 3 of these signs visible.⁸⁶

Hypoplasia of either the medial or lateral femoral condyle can also contribute to abnormal trochlear anatomy and subsequent PF articulation abnormality. Measurements of trochlear depth are best made on midsagittal MR images 3 cm above the femorotibial joint.⁸⁷ Others may assess trochlear dysplasia on the most proximal cranio-caudal transverse image on which the cartilage along the entire width of the trochlea is visible.⁸⁸

Patellar Dysplasia

As abnormal anatomy predisposes to development of pathology, patellar morphology is worth review. The lateral facet is typically longer and more sloped than the medial facet in order to match the lateral femoral condyle, while the medial facet is smaller, with a shorter and consequently steeper slope. The lateral facet is larger and extends more proximally than the medial facet. The Wiberg classification delineates 4 different types of patellar morphology based on the location of the median ridge.⁸⁹ Wiberg Type I patellas have nearly symmetrical, concave medial, and lateral facets. Types II-IV has progressively more convex and smaller medial facets with subsequently longer lateral facets. High incidence and larger size articular cartilage defects are associated with higher degrees of patellar dysplasia⁹⁰ (Fig. 7).

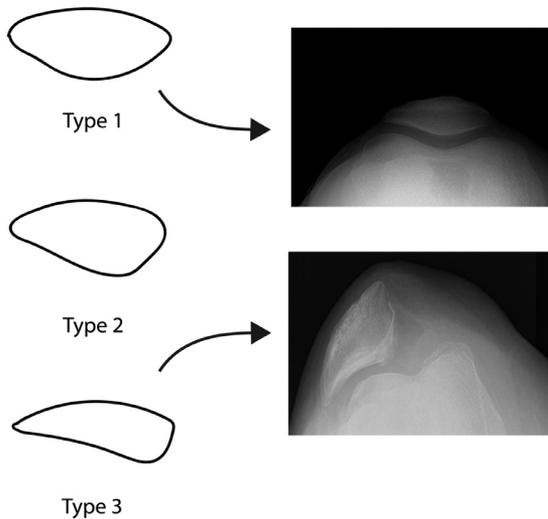


Figure 7 Wiberg classification.

Post-traumatic Findings

Articular cartilage abnormalities, ranging from focal defects to PFJ arthritis, are a common cause of anterior knee pain. Osteochondral abnormalities that are often present following trauma include fractures, chondral delaminating injuries that may or may not include a portion of subchondral bone, as well as hybrid injuries such as osteochondritis dissecans. Chondral injuries have been reported to occur in up to 33% of patients who sustain a patellar dislocation.^{2,88,91} Chondral injuries may produce loose bodies within the knee. MRI is the best imaging modality to detect the presence of chondral injuries and loose bodies, and can further assist in the decision-making regarding treatment options and surgical planning. (Fig. 8) These loose bodies usually present as separate chondral or osteochondral fragments originating from the medial patella or lateral femoral condyle.^{2,88,91} Injuries to cartilage can be both structural (fibrillation, flaps, fissures, and defects of various depths) and ultra-structural, affecting the compositional makeup of the cartilage (water, collagen, etc) which may present as chondral softening appreciated at the time of arthroscopy or on cartilage mapping techniques described earlier.³⁷

A classification system for cartilage abnormalities was developed in 1997 by the International Cartilage Repair Society (ICRS), and is based on the Outerbridge arthroscopic classification system. This system divides lesions into 4 grades based on depth.⁹² The ICRS classification system uses the same 4 grades as Outerbridge and describes the corresponding MRI findings⁹³ (Table 2). Traumatic chondral lesions can also be graded using semiquantitative scoring systems such as the Whole-Organ Magnetic Resonance Imaging Score (WORMS) and the MRI Osteoarthritis Knee Score (MOAKS), which contain subscales specifically for cartilage injury.^{94,95} The WORMS grading protocol uses an 8-point scale to score cartilage morphology and evaluates for subarticular cysts, bone attrition, and osteophytes. The MOAKS grading protocol, in addition to cartilage assessment, evaluates bone marrow lesions and meniscal abnormalities.



Figure 8 Patella dislocation demonstrating bone edema pattern (left) and loose bodies (right).

Generally, high-grade chondral lesions are considered to be those that affect >50% of the cartilage thickness on either the patella or trochlea.

The majority of patients who sustain a dislocation and spontaneous reduction will have persistent patellar subluxation or tilt due to concomitant MPFL/medial retinacular complex injury and joint effusion.² In patient who sustain a lateral patellar dislocation, reduction often occurs prior to imaging, and the clinical presentation is often nonspecific, characterized by acute knee pain and swelling. In this setting, hallmark features on imaging assists in diagnosis. MRI allows for identification of underlying anatomy, bone marrow contusions consistent with dislocation, medial retinaculum tear

Table 2 Outerbridge and ICRS Grading Systems

ICRS Grading System	
0	Normal
1	Nearly normal
2	Abnormal
3	Severely abnormal
4	Severely abnormal
A	Soft indentation
B	Superficial fissures and cracks involving <50% cartilage depth
A	Involving >50% cartilage depth
B	Involving the calcified layer
C	Down to, but not through, subchondral bone
D	Blistering
	Penetration through subchondral bone
Outerbridge Grading System	
0	Normal
1	Softening and swelling of articular cartilage
2	Fragmentation and fissuring that does not reach subchondral bone with a diameter < 1.5 cm
3	Fragmentation and fissuring to the level of subchondral bone with a diameter > 1.5 cm
4	Cartilage erosion to subchondral bone

or MPFL injury, and identification of osteochondral injury and loose fragments.

The normal MPFL attaches between the adductor tubercle and medial epicondyle. While almost every patient will demonstrate an injury pattern on the patellar side following an acute dislocation event, identification of MPFL or medial retinacular complex tears as well as the location (femoral vs patellar) is important. Femoral-sided injury is indicated by proximal edema at the anterior aspect of the proximal medial collateral ligament.² The MPFL itself can often be difficult to discern, especially if surrounding soft tissues demonstrates localized edema, as is often the case following an acute injury. However, multiple studies demonstrate that MRI is roughly 85% sensitive and 70% accurate in the detection of MPFL tears, thereby supporting the conclusion that MRI is a valuable imaging modality if such an injury is suspected.⁹⁶

When the patella dislocates laterally, the inferomedial aspect of the patella impacts against the anterolateral aspect of the lateral femoral condyle as it reduces medially back into the trochlea, causing bone marrow contusions seen as focal areas of bone edema. The contusion on the lateral femoral condyle is more anterior, superior, and lateral than those seen in the pivot shift of anterior cruciate ligament tears.⁸⁸ More rarely, a shear-type fracture may occur along the lateral femoral condyle.⁹⁷ Inferomedial patellar osteochondral injuries are reported in up to 70% of patients following patellar dislocation.⁹¹

Overuse Findings

Overuse injuries are common among subspecialized athletes performing repetitive motions but are also encountered in the general population. Overuse injuries that may lead to PF pain include tendinosis of the quadriceps and patellar tendons, prepatellar bursitis, fat pad impingement, and PF overload. These injury patterns typically result from repetitive activity or sudden increases in activity, frequency, or intensity. Similarly, traction-related mechanisms can cause anterior knee pain. Traction apophysitis may affect the patellar tendon insertion on the tibial tuberosity in Osgood-Schlatter syndrome or at the inferior pole of the patella in Sinding-Larsen-Johansson syndrome (Fig. 9). Both of these are characterized by increased signal and edema within the respective site of pain on fluid sensitive sequences. If elevated signal is appreciated within the tendon itself, this may represent patellar tendinosis and reflects more advanced structural degeneration within the tendon and results in decreased tensile resistive strength and function. These changes can be observed within the quadriceps tendon in similar cases of quadriceps tendinosis. Ultrasound can also be used to observe these changes, but the quality of imaging is operator dependent.

Plicae are remnants of embryologic tissue in the knee that may cause medial PF pain or mechanical clicking or snapping.⁹⁸ These are not truly a post-traumatic change but may lead to development of synovitis, knee pain, restricted knee or PF motion, and altered forces about the PF joint. The band of tissue itself can also cause injury to the chondral surface by direct pressure. Plicae bands can be observed on MRI or Ultrasound. They are often medially based within the knee.



Figure 9 Osgood Schlatter's disease.

Fat pad impingement is an important and more recently recognized source of anterior knee pain. It is often associated with at least some degree of PF dysplasia, and usually presents with predominantly nonradiating anterior knee pain. It is best diagnosed on MRI, where any of the 3 fat pads (anterior suprapatellar, posterior suprapatellar, and infrapatellar) demonstrate increased signal intensity on fluid-sensitive sequences. The lateral aspect of the infrapatellar fat is most commonly affected. The etiology of fat pad impingement is multifactorial and includes PF instability, repetitive microtrauma, or direct trauma, and patella alta, all of which may cause injury to the fat pads and lead to hemorrhage, inflammation, pain, and eventual fibrosis of the tissue.⁹⁹

Iliotibial band syndrome and certain forms of fat pad impingement may be different manifestations of a recently-recognized entity known as lateral PF overload syndrome.¹⁰⁰ Even with normal anatomy and biomechanics, the forces that the PFJ experiences are very high, and may exceed 2-5 times body weight with normal activities, and 7-8 times body weight with squatting in high knee flexion.⁸² Thus, abnormal patellar tilt and tight retinacular structures can lead to increasingly abnormal forces across the PFJ, which in turn predisposes this area to chondral degeneration.¹⁰¹ This overload often occurs in patients with activity-related symptoms who demonstrate findings of superolateral fat pad impingement and/or iliotibial band syndrome on MRI. When imaged after provocative activity, features of both iliotibial band and lateral PF overload syndromes can often be seen concomitantly.

Osteochondritis Dissecans

Osteochondritis Dissecans (OCD) lesions, though more commonly encountered in the femorotibial compartment, can occur along either the patella or trochlea.^{102,103} OCD lesions involve partial or complete separation of the articular cartilage and subchondral bone from an articular surface.^{104,105} When found in the PF compartment, OCD lesions most often present as symptoms associated with running or jumping. Lesions in the PFJ are often undetected on plain radiographs. Therefore, these lesions may remain undiagnosed for

longer periods. When OCD lesions involve the femoral sulcus, they may be best observed on a Merchant view. In this location, they typically occur where the lateral femoral condyle contacts the lateral facet of the patella.¹⁰² Lesions involving the patella are more variable but are most commonly found along the central lateral facet, central medial facet, and inferior medial facet.¹⁰³

The size and stability of chondral defects have important prognostic implications and can assist in treatment planning for knee OCD lesions.¹⁰⁶ Unstable OCD lesions are best characterized by a high signal intensity cleft between the osteochondritic fragment and the underlying bone.¹⁰⁶⁻¹⁰⁸ Other MR criteria commonly to evaluate OCD fragment instability include associated cysts, high T2 signal intensity cartilage fracture line or a fluid-filled OCD defect¹⁰⁷ (Fig. 10).

Osteoarthritis

Isolated PF osteoarthritis is uncommon when compared to femorotibial compartments or tricompartmental. The incidence of isolated PF osteoarthritis is approximately 13%-15% in symptomatic patients >60 years of age and in about 19% of asymptomatic men and 34% of asymptomatic women.^{109,110} Specific risk factors for development of PFJ osteoarthritis often overlap with risk factors for PF pain and instability and include patella alta, trochlear dysplasia, PF malalignment, and calcium pyrophosphate deposition disease. Interestingly, in a 7-year follow-up longitudinal study, most knees with multicompartmental osteoarthritis first started with isolated damage to the PFJ.¹¹¹

Incidental Findings

Bipartite patella results from failed fusion of a secondary ossification center with the body of the patella during development. This phenomenon is bilateral in 40% of cases, and is 9 times more common in males.¹¹² The associated overlying articular cartilage of the patella is usually still intact and is asymptomatic. However, in the setting of trauma or overuse, the synchondrosis may be disrupted at the failed fusion site,

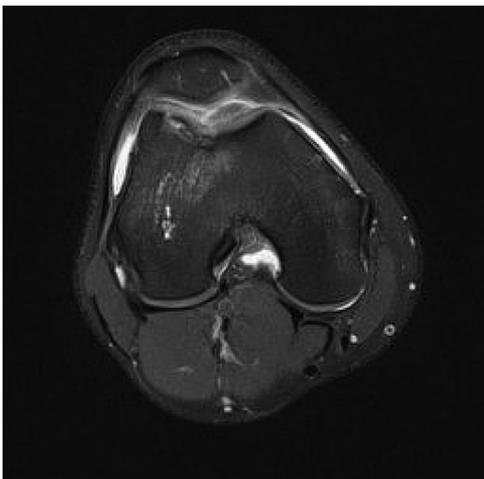


Figure 10 Trochlea osteochondral dissecans (OCD) lesion.



Figure 11 Asymptomatic bipartite patella.

causing abnormal motion or friction with resultant pain and associated bone marrow edema which can be appreciated on MRI (Fig. 11).

Conclusion

PF disorders encompass a wide spectrum of disease and result from an array of etiologies. A number of anatomic abnormalities, such as PF malalignment, maltracking, and dysplasia predispose individuals to altered PFJ forces and mechanics. Imaging modalities are useful in evaluating morphologic changes, location, and presence of injured soft tissues and osteochondral structures and defining inherent structural relationships. Imaging of the PFJ should be used to confirm clinical suspicion based on symptoms and exam, provide insight regarding present pathology, and further plan treatment options.

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