IMAGING STUDIES OF THE PATELLOFEMORAL JOINT: OUR CURRENT REALITY

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Abstract: Patellofemoral dysfunction (PFD) is a common cause for medical consultation and in a broad sense it refers to a condition in which the patella fails to engage securely in the trochlear groove. This is a topic in which terminology is often ambiguous and confusing due, inter alia, to the discrepancy between symptomatology, imaging findings and physical examination. In addition, PFD has a multifactorial etiology that includes local anatomical, rotational and dynamic factors, with no certainty about their real influence. From the imaging point of view, there are countless publications proposing different classifications and measurements obtained through different imaging techniques; however, there is no consensus regarding what are the anatomical alterations or the normal values that imaging reports should include. A review of the existing literature is performed and we propose that patients with PFD should undergo both a radiological study comprising etiologic and anatomic factors and a second-line tomographic exploration including lower extremity rotational profiles. From the radiological and clinical viewpoints, relevant issues to be considered
as well as assessments performed should be systematized and recorded in a report sheet.

**Keywords:** Anatomical factors, Dynamic factors, Patellar subluxation, Patellar tilt, Patellofemoral dysfunction, Trochlear dysplasia.

**Introduction**

Anterior knee pain is a common complaint in orthopaedics and traumatology consultation. In general terms, patellofemoral dysfunction (PFD) refers to a condition in which the patella fails to engage properly in the trochlear groove. This is a complex issue in which terminology is often ambiguous and confusing due, inter alia, to the discrepancy between symptomatology, imaging findings and physical examination.

Alterations of this joint is the least understood condition in knee pathology. Patellofemoral mechanics is complex and the etiology of its pathology is multifactorial.

In imaging studies, there is a wide range of normality and inconsistent use of terminology within the scientific community occurs, since terms of basic sciences appear interweaved with clinical diagnoses and syndromes, thus hindering both a proper etiological diagnosis and the therapeutic approach, as established by the International Patellofemoral Pathology Study Group (IPSG). Different terms, such as patellofemoral malalignment, patellofemoral chondromalacia patellofemoral instability, anterior knee pain and patellofemoral dysfunction are indistinctly used to refer to the same entity.

This review examines the anatomic factors conditioning objective patellar instability and we propose an imaging study protocol to investigate direct factors originated in the patellofemoral joint (PFJ), and indirect factors, arising in rotational changes.

**Development**

Currently, there is consensus in trying to define diagnoses that reflect the etiology of the clinical picture by separating extrinsic factors- acute trauma and repetitive trauma overload)- from intrinsic factors, i.e., the anatomical elements that influence biomechanical alterations. Anatomical factors are determined by muscles, tendons,
bones and developmental problems of the musculoskeletal system. Some of these factors can be depicted on imaging studies.

Probably, the most useful classification was proposed in 1978 when Dejour, Hughston and Fulkerson \(^{(1)}\) almost simultaneously described the clinical picture of atellofemoral malalignment, separating it into three groups:

1. History of patellofemoral pain without etiologic anatomical factors.
2. History of patellofemoral pain with anatomical factors.
3. History of dislocation with anatomical factors.

The current nomenclature most widely used is perhaps the one proposed by the French group that classifies the problem in three clinical pictures:

1. Objective instability with anatomic factors: patients with repeated episodes of patellofemoral dislocation.
2. Potential instability: patients presenting without dislocation but with pain and anatomical factors.
3. Pain without instability or anatomic factors \(^{(2)}\).

At present it is set out that patellar instability could have a multifactorial etiology with anatomical-morphological and dynamic factors (Table I) originated in the PFJ and the entire limb, causing an imbalance between the forces that control patellar traction during knee flexion and extension, which in turn provokes articulation overload \(^{(3)}\). There is no clear understanding on the actual influence that the different anatomical factors already described exert on the PFD.

From the standpoint of imaging techniques, numerous publications with different classifications and measurements are currently available; however, there is no consensus regarding what are the anatomic alterations or normal values an imaging report should include.
Radiological assessment of PFJ

Evaluation of PFJ should always begin with a plain radiological study (plain x-rays)\(^{(4)}\), including three sequences: anteroposterior, lateral and axial projections with a flexion less than 30 degrees. Why less than 30 degrees? Because studies have shown that 97% of the normal individuals have patella centered at 30 degrees and greater flexion will translate into the reduction of most of the alignment abnormalities\(^{(5)}\).

On plain radiographs, mainly femorotibial joint space, traumatic injuries or tumors, and patellar findings such as fractures, bipartite patella, dorsal patellar defect, etc. can be assessed (Figure 1). AP projection radiography is the one providing the poorest information about the PFJ.

![Figure 1. AP knee projection](image)

The knee should be flexed no more that 30 degrees when performing lateral knee radiography. A proper lateral projection is the one in which posterior portions of femoral condyles are superimposed. In these conditions, three dense lines in the anterior aspect of the distal femoral epiphysis can be identified: the two anterior lines correlate with the anterior outline of femoral condyles, while posterior line corresponds to the trochlear sulcus\(^{(6)}\) (Figure 2). It is important to know the limitations of this projection
which is dependant on both the technologist and the patient, since the variability in its implementation makes it difficult to obtain a real projection performed at less than 30 degrees of knee flexion.

![Lateral radiograph of good quality; posterior femoral condyles superimposed are shown.](image)

**Figure 2.** *Lateral radiograph of good quality; posterior femoral condyles superimposed are shown.*

The 30-degrees axial projection is performed as described by Merchant\(^7\), with the patient with flexed knees, the chassis on his legs and a horizontal beam angle of 30 degrees. The same considerations for radiography in lateral projection are applied here concerning variability of image acquisition as well as difficulty for obtaining a projection with flexion angle less than 30 degrees; therefore, plain radiography measurements would be of limited value.

Computed tomography (CT) scan technique renders images at different knee flexion angles, more accurate measurements as compared to plain radiographs, and performs imaging overlapping\(^5\). This diagnostic procedure also permits to carry out measurements with contraction of the quadriceps muscle, which according to what has been described in the literature increases the sensitivity of the study due to worsening of abnormal values and occurrence of abnormality in patients with normal values at rest\(^6\).
Magnetic resonance imaging (MRI) mainly assesses soft tissues: retinacula, patellar and quadricipital tendon, quadriceps muscle and patellar and trochlear cartilages, making evident degenerative changes in cartilages, chondral injuries, etc (8) (Figures 3 and 4).

**Figure 3.** Traumatic patellar dislocation. FSDP axial MRI sequence showing rupture of the medial retinaculum.

**Figure 4.** FSDP axial MRI sequence showing patella with cartilage thinning of irregular margin, with impaired internal signal and chondromalasic appearance.
Assessment of dynamic factors

Attempts have been made to evaluate PFJ dynamically, to establish the behavior and interaction of anatomical structures involved in flexion and extension.

As for dynamic MRI to assess the PFJ, there are studies that reproduce the dynamic behavior of the joint in bipedestation, since "static" measures of plain radiograph fail to reveal the relationship between the trochlea and the patella in the first 30 degrees of flexion. It has been shown to be a useful and sensitive technique that allows that soft structures influencing the stability and function of the joint may be identified. This is an important information since abnormalities in these structures (patellar tendon, retinacula and quadriceps) are often important factors in these alterations (9).

There are several techniques for dynamic MRI studies:

1. **Placement technique with passive increase**: multiple axial images are obtained at different levels while the joint is progressively and passively flexed by using a non-ferromagnetic support managed by the patient. The study is performed in supine-prone position and images with increments of 5 degrees are obtained, from 0° to 30° of flexion. Some studies have demonstrated that this technique is appropriate for evaluating the alignment and path of the patella.

2. **Active movement technique**: allows to obtain images during movement. Its main advantage lies in that it considers the influence of muscles and soft tissues. It is performed in supine-prone position from 45 degrees of flexion to full extension. As compared to the prior procedure, it allows a more physiological assessment and sometimes an abnormal path of the patella becomes more evident.

3. **Film series technique**: using a special non-ferromagnetic holder, which incorporates a trigger that senses movement of the patella. Patient is placed in decubitus-supine position, flexing and extending the knee repeatedly. This technique shows patterns of patellar paths different to those obtained by the technique of placement with passive increase.

4. **Technique of active movement against resistance**: in this case, the test is performed during the active movement by opposing an external load.
Adding resistance to the exam allows to observe changes that may not be detected in no-load test, which makes it a best technique for identifying abnormal positions of the patella. This is performed in the decubitus prone position with a device that applies an adjustable resistance to be bilaterally analyzed from 45 degrees to full knee extension.

All articles published so far show that on dynamic MRI the clinical suspicion of altered path of the patella is confirmed; however, its actual usefulness remains controversial. Pioneering centers assert that the understanding of patellar alignment could influence both the treatment and the appropriate surgical procedure. However, to date there are no published studies documenting the capability of dynamic MRI to guide treatment and predict its outcome.

**Evaluation of anatomical morphological factors**

The aim of this review is, on the one hand, to analyze the most important "static" etiological factors that play a role in the objective patellar instability, which can be shown on imaging studies, and, on the other hand, to propose a standardized protocol of the imaging report for CT, including the local factors of the PFJ as well as the indirect factors, such as lower limb rotational alterations.

Anatomical factors are summarized in Table I. They are classified into local (originating from the very PFJ) and rotational (originating from the rotational axis of the limb) (1):

I. Local factors: femoral trochlea, patella, anterior tibial tuberosity, soft tissues and relationship between the trochlea and the patella.

II. Rotational factors: acetabular anteversion (AA), femoral anteversion (FAV), external tibial torsion (ETT), genu valgus and genu recurvatum.

**Table I. Etiological factors related to patellofemoral dysfunction**

A. - *Anatomical Factors*

I. Local:
   1) Femoral trochlea
2) Patella
3) anterior tibial tuberosity
4) Soft tissues
5) Relationship between the trochlea and the patella

II. Rotational:
   - Acetabular anteversion (AA)
   - Femoral anteversion (FAV)
   - External tibial torsion (ETT)
   - Genu valgum, genu recurvatum

B. Dynamic factors
Interaction of the anatomical structures during flexion and extension

AI. Local anatomical factors

1. **Femoral trochlea**: The morphology of the trochlea is a factor that influences the stability of the patella in the joint. Trochlear dysplasia is an anatomical malformation located in the upper third of the articular surface of the trochlea, which is due to abnormalities in the growth of articular facets and constitutes a fundamental and permanent factor in the objective patellar instability. The slightly pronounced lateral slope of the lateral condyle is responsible for a flat trochlea; the trochlear groove has an insufficient depth and therefore it is unable to retain the patella. In highly severe cases of dysplasia, the lateral facet may be convex which is associated with hypoplasia of the medial condyle. It is important to determine both the opening and the depth of the groove, since its alteration determines dysplasia and, therefore, instability.

**MR Imaging evaluation of the femoral trochlea**

a) **Trochlear angle**: The opening angle of the trochlea is measured, which is normally 138 degrees \(^{11}\); trochlear dysplasia is defined as the excessive opening of this angle. In the axial cut, an angle between the deepest point of the trochlea groove and the upper and most anterior points of both femoral condyles is determined. This measurement is recommended in the cut in which the medial side is one third of the lateral side in the CT axial cut \(^{12}\). Trochlear dysplasia is determined if the angle is $> 140 \, ^\circ$ (Figure 5).

b) **Trochlear depth**: In lateral knee radiography it is determined by drawing a line tangent to the posterior cortical surface of the distal femur (a), followed by another line
perpendicular to it, at the level of posterior and superior margin of the femoral condyles (b); finally a third line is drawn (c) with an angle of 15° distal to b line; this line crosses the trochlear groove and the condylar crests. By following line c, the depth of the trochlea corresponds to the distance measured in mm between the bottom of the trochlea and the anterior condylar edge. In normal knees, depth is 7.8 mm and in knees with patellar instability is 0.1 mm (6) (Figure 6).

c) Bump or supratrochlear spur: It is measured by strict lateral radiography, i.e., with overlapping of the femoral condyles. This parameter allows to locate and quantify the position of the trochlear bottom (A) in relation to the anterior cortical surface of the femur (B). A line tangential to the last 10 cm of the anterior cortical surface of the femur (line x) is drawn. The trochlear bottom line may extend in front of the cortical line (positive value), over the cortical line (neutral value) or behind it (negative value) (Figure 7). The bump corresponds to the AB distance (between the bottom of the trochlea and the anterior cortical surface of the femur) and is expressed in mm. The image of the protrusion has also been called "supratrochlear spur"; the larger the spur, the greater the dysplasia. According to Dejour, in normal knees the protrusion is, on average, 0.8 mm and in unstable knees, 3.1 mm on average (6).

d) Crossing sign: It is evaluated with lateral radiography. In normal conditions this imaging technique shows the existence of three lines formed by the contour of the femoral condyles and the bottom of the trochlea. The internal condyle is recognized because it has an anterior notch less marked if compared with the one of the lateral condyle. The third line (posterior to previous two lines) is the line of the bottom of the trochlea and extends backwards with the Blumensaat’s line in the intercondylar notch. In normal conditions, the bottom line of the trochlea is parallel to the profiles of the femoral condyles; the ending pattern of this line allows us to define two types of normal trochleas: Type A, when no crossing exists between the bottom of the trochlea and femoral condyles, and Type B, when the bottom line of the trochlea crosses the medial condyle in isolation.

In patellar instability, the bottom line crosses the internal and external condyles more or less below depending on the severity of dysplasia. This sign is of great semiological value and constitutes a qualitative criterion of trochlear dysplasia. The crossing sign is
seen in 96% of objective instabilities, in 12% of patellofemoral pain syndrome, and in only 2% of normal knees.

**Figure 5.** Trochlear angle: CT measurement. An angle between the deepest point of the trochlea and the most superior and anterior points of both femoral condyles is determined; this measurement is made at the point where the medial side is one third of the lateral aspect. Existence of trochlear dysplasia is determined if the angle is > 140°.

**Figure 6.** Measurement of trochlear depth on plain radiograph, lateral projection.
Dejour has defined three types of dysplasia according to the level of crossing:

Type I: It corresponds to the mildest form of dysplasia. The lines of the condyles are symmetrical and intersect at the same point in the proximal part of the trochlea; the trochlea is flat only in its uppermost part (Figure 8a).

Type II: This type of dysplasia is characterized by a crossing occurring at different levels of condylar lines. These lines do not overlap, but the bottom line of the trochlea first crosses the internal condyle and then the external condyle; as the level of crossing goes down, the severity of dysplasia increases (Figure 8b).

Type III: This is the most severe form of dysplasia. Lines of condyles overlap, intersecting with the bottom line of the trochlea at a very low level (Figure 8c) (6).

Figure 7. *Trochlear bump with negative value: vertical line passes behind the groove*

Figure 8 a, b, c. *Scheme of trochlear dysplasia type I, II, and III according to Dejour.*
In summary, there are several ways to objectify the presence of trochlear displasia. We have used the trochlear angle, the crossing sign as depicted by both lateral knee radiography and CT (to be addressed below), and the presence of supratrochlear spur.

2. **Patella:** The patella is part of the extensor apparatus of the knee. The patellar cartilage is the thickest cartilage in the human body and it is well prepared to resist major compressive forces. The function of the patella is to improve the efficiency of the quadriceps muscle by increasing the lever arm of the extensor mechanism. This is due to that the patella displaces the patellar tendon outside the tibiofemoral contact point during movement, thus increasing the lever arm; it centralizes tensile forces of the quadriceps to the patellar tendon and tibial tuberosity, distributes pressure on the femoral trochlea, and stabilizes the knee during rotation.

    a) **Position:** High patella is one of the most important factors favoring etiological instability, as it is present in 30-50 percent of the objective patellar instabilities \(^{(13)}\); occasionally, it is the only anatomical factor present. It is often bilateral and is frequently found in recurrent dislocation \(^{(11)}\). It is conditioned by the presence of an abnormally long patellar tendon, which prevents the patella from sitting properly into the trochlea, along with lateral subluxation due to precocious tension of lateral retinaculum at the start of flexion. Patella alta results in less osseous stability because a greater degree of flexion is required to fit into the trochlea if compared with a normal knee \(^{(14)}\), where patella enters at 20 degrees of knee flexion \(^{(12)}\).

Currently, plain radiography is used to measure the height of the patella. Different measurement indicators have been described, among which Insall-Salvati index and Caton-Deschamps index may be cited as the most widely used techniques in objective patellar instability \(^{(14)}\). According to Insall-Salvati the relationship between patellar tendon length and maximum diameter of the patella is considered to determine patella alta, i.e., index > 1.2 whereas < 0.8 indicates the presence of patella baja \(^{(10)}\) (Figure 9).
Figure 9. Insall-Salvati: measurement on plain lateral projection MRI. Patella alta: IS ratio > to 1.2 and patella baja: IS index < 0.8.

According to Caton, the ratio between the lowest point from the patella to the anterosuperior tibial plateau and the length of the articular surface of the patella is determined; patella alta is present if index > 1.2, and patella baja if index < 0.6. (11) (Figure 10).

Figure 10. Caton: Plain radiograph measurement in lateral projection. Patella alta: index > 1.2 and patella baja: index < 0.6.
b. - Morphology: Wiberg (in 1941) classified the patella according to the morphology of the internal aspect in three types, and Baumgartl (in 1944) added another variant:

Type I: The internal facet has a smooth concavity with same measure as the external aspect. (10% of cases)

Type II: The internal facet is shorter than the lateral aspect, flat or slightly convex. (65% cases)

Type III: The internal facet is very small compared with the lateral face, and convex almost vertical; this type of patella correlates with instability (Figure 11).

Type IV: This is characterized by the absence of both medial crest and internal facet (hunter’s cap.)

![Image of patella]

**Figure 11.** Wiberg type II: asymmetric patellar facets, with a smaller medial facet

3. Anterior tibial tuberosity (ATT): The exceedingly lateral position of the ATT is one of the anatomical changes more frequently mentioned and perhaps the one that has led to greater number of surgeries. ATT position determines the valgus of the extensor apparatus of the knee, and the distance between the ATT and the trochlear sulcus objectifies the valgus vector of the extensor apparatus.

How to evaluate images? With the distance ITS-ATT (intertrochlear sulcus/ Anterior tibial tuberosity). This measurement is performed with overlapping of axial CT cuts made at different levels: one in the trochlea, where the medial side is one third of the lateral aspect and the other through the anterior tibial tuberosity. A vertical line passing through the deepest point of the trochlea is drawn and then a second line parallel to the
previous one, which passes through the ATT. The distance between them should be less than 15 mm; if the value is greater, the distance ITS-ATT is considered as increased and pathological; (11) this constitutes a measurement of the ATT external translation as related to the trochlear groove in the sagittal plane. (Figure 12).

![Image of measurement](image.png)

**Figure 12.** Measurement of ITS-ATT distance through superimposition of axial CT cuts. The image shows an increased ITS-ATT distance.

Q angle is measured between the axis of the vastus lateralis of the quadriceps and the axis of the patellar tendon, that is, its insertion into the ATT (Figure 13). Q angle (10) translates the tensile force of the quad muscle on the patella, determining the magnitude of the luxating force towards lateral position; it indirectly measures lateralization of ATT or distal insertion of the patellar tendon. When the knee is near extension, muscle contraction tends to displace the patella laterally, because of the presence of the Q angle. During maximum extension, the tibia is externally rotated, thus displacing ATT laterally. This increases the Q angle, maximizing the luxating force towards lateral position; therefore, it is in this extended position when the patella has a higher risk of dislocation (3).
Figure 13. *Q angle:* Obtained from anterior superior iliac spine line, at the center of the patella, and another line extending between the patellar center and the anterior tibial tuberosity.

4. Soft tissues

- Medial patellofemoral ligament: It is a part of the medial retinaculum, the main passive restraint to lateral patellar displacement\(^{(10,12)}\). It pulls the patella medially and it has been reported to restrain approximately 50-60\% of lateral patellar displacement between 0 and 30 degrees of flexion\(^{(16)}\). There is no imaging method capable of evaluating its dynamic role in instability; on MRI it is possible to assess its morphological characteristics.

- Quadriceps muscle and tendon: Four muscle components are attached distally in a three-layer tendon; the most superficial fibers of the anterior rectus join the patellar tendon and the deepest insert into the upper pole of the patella. Vastus medialis and vastus lateralis form the intermediate layer; these muscles send fibers to the retinacula. The vastus medialis is composed of two portions, the vastus medialis oblique and the vastus medialis longus; fibers of the vastus medialis oblique have a more oblique downwards and outwards orientation, and therefore they are more appropriate to limit the lateral displacement of the patella. The angle at which oblique fibers reach the patella varies between 55 \ and 70 degrees in relation to the major axis of the quadriceps tendon. The vastus medialis oblique becomes tendinosus a few millimeters from its
insertion into the upper third or in the midpart of the medial edge of the patella\textsuperscript{(10)}. Another anatomical factor involved in patellar instability is an anatomical malformation of the quadriceps femoral muscle, the so-called dysplasia of the quadriceps. This morphological anomaly has two essential aspects: short quadriceps and dysplasia of the vastus medialis. This is an alteration in the insertion of the vastus medialis into the patella; the more distal fibers of the muscle insert into the superomedial angle rather than into the medial border. This dystrophy in muscle insertion unbalances the biomechanics of the quadriceps, increases valgus of the knee extensor system, and is responsible for increased lateral subluxation forces of the patella, thus promoting instability.

Some authors have reported the existence of dysplasia of the vastus lateralis muscle, which presents in the form of an anomalous low insertion of the vastus lateralis fibers over the lateral aspect of the patella, which is associated with retraction of the lateral retinaculum or external wing.

The clinical evaluation of dysplasia of both vastus is subjective due to the difficulty posed by the exam. To quantify dysplasia, it has been proposed that the indirect measurable factor would be the "patellar scales" (knee in extension), which can be studied on CT, with and without quadriceps muscle contraction.

5. Relationship between the trochlea and the patella

The relationship of these two anatomical factors, trochlea and patella, is studied using the following measurements:

• *Patellofemoral angle according to Laurin*\textsuperscript{(17)}: The patellar bascule refers to the transverse orientation of the patella. Laurin describes measurement of patellofemoral angle on axial projection plain radiography, with 20° flexion of the knee. It is measured by drawing two straight lines; the first line intersects the most anterior point of the condyles and the other line is tangent to the lateral patellar facet. The angle formed is positive when it opens outward, void when the two lines are parallel, or negative when they open inwards. It allows measurement of the lateral patellofemoral opening angle, which in normal knees opens externally in 97% of cases (Figure 14).
Figure 14. Laurin’s normal patellofemoral angle opens laterally on plain axial projection radiograph at 20 degrees.

- **External patellar tilt:** Another measurement of the patellar bascula is performed on CT scan, axial cut passing by the middle of the patella and corresponds to the angle formed by the transverse axis of the patella and the posterior bicondylar line. This measurement is performed with the knee in extension, with and without contraction of the quadriceps muscle, also at 15 ° of flexion. It reflects both dysplasia of the quadriceps muscle (vastus medialis) and dysplasia of the trochlea. Exploration with and without quadriceps contraction allows dynamic assessment of the bascula. In 97% of normal subjects, the trochlear bascula is 10 ° to 20 °, while it is > 20 ° in 83% of patients with objective instability (18).

- **Congruence angle:** The Merchant congruence angle (11) is used to determine patella subluxation. It is obtained by marking out the bisection of the angle of the trochlea in flexion and then a line joining the bottom of the trochlea and the crest of the patella; the angle formed between both lines is the congruence angle. If the tip of the patella is located outside the bisection, the angle is positive and demonstrates a rather external subluxation; if the tip is located in the bisector inner surface, it is negative and indicative of internal subluxation. If the medial displacement is > 11 ° and the lateral displacement is > 6 °, subluxation is determined (11) (Figure 15).
A II - Anatomical rotational factors

Rotational anatomy of the femur and tibia are different. In the coronal plane, the femoral extends from an abduction position at proximal level (due to the width of the pelvic ring) to a theoretically ideal position that allows patients to have tibias parallel to each other; in this same plane, the distal articular surface of the femur has a physiological valgus of 5 to 7 degrees. The tibia in the frontal plane keeps straight and generally maintains the femoral axis; ATT is in a lateral position, which affects Q angle of the extensor apparatus, thanks to which a good control of internal rotation and locking of the knee in full extension is obtained.

In the sagittal plane, the femur presents a curve with posterior concavity, while the tibia has an important posterior concave curved surface at the segment proximal to the patellar tendon insertion, which makes the plane of the tibial plateau to be tilted about 5 degrees backwards.

In the horizontal plane, the femur exhibits an anteversion of approximately 15°, which is characteristic of upright posture in human beings; there is no other animal with femoral torsion. To compensate for this anteversion, there is an external tibial torsion occurring in the first centimeters of the proximal epiphysis of about 35 degrees, thus allowing feet to run parallel during walking (19). Rotations affecting the femoro-patellar dynamics occur between the femur and tibia. Due to the arrangement of cruciate ligaments, there is a greater capacity of external rotation at knee level, which produces an even more lateral insertion of the patellar tendon.

These anatomic features are then indirect conditioning factors of PFJ stability, and therefore it is useful to know the following additional measures: acetabular anteversion (AA), femoral anteversion (FAV) and external tibial torsion (ETT) (20). A statistical relationship between recurrent dislocation of the patella and increased ETT and FAV has been demonstrated; similarly, there is a related anterior knee pain if the FAV is associated with an increase in ETT (19).

Acetabular version is the normal inclination of the acetabulum in relation to the sagittal plane; it is defined by the intersection of the sagittal plane of the body and the plane parallel to the edges of the acetabulum. Histomorphometric studies have shown that the acetabular anteversion remains constant during the first half of intrauterine life (21).
Acetabular version, remains relatively constant during childhood with an average value of 13 degrees \(^{22}\). These findings suggest that acetabular version is not a common factor in rotational problems. To evaluate these measures, CT scanning capability allowing overlapping of cuts performed at different levels is used.

FAV is the angle formed between the axis of the femoral neck and the posterior bicondylar line \(^{23}\), while ETT is the angle formed by the posterior tangent of the tibial epiphysis and the bimalleolar axis \(^{23}\); normal values of both measures are described below.

**Proposal**

Patellar instability or PFD is a multifactorial disease and the current role of imaging techniques is to objectify the "static" anatomical factors determining patellar instability. The imaging study of PFJ has developed over time, according to emergence of different study techniques, such as x-ray, CT scan and even MRI for current evaluation of PFJ. We propose that the study of patellar instability should include plain x-rays, as described above, and CT explorations as a second-line examination including a rotational study of lower limbs to determine the most significant referential points to study patellar instability.

![Image of congruence angle](image)

**Figure 15.** Angle of congruence as described by Merchant, axial view at 20° in plain radiograph.

**Computed tomography study**

---Technique (23):

Patient in supine position with external rotation of lower extremities of 15° \(^{6}\). With knees in extension, a sweep through hips, knees and ankles is performed, and another
sweep across the knees flexed at 20 ° is also carried out. A technique of 150 kV and 5 mA is applied. According to what has been described, an external rotation of limbs of 15 °, potential abnormalities of alignment are accentuated, whereas a flexion angle of 20 ° permits that most of the alterations in position and trayectory occurring in the range between 0° and 30 ° of flexion may be observed (Figure 16).

Figure 16. Scout view of patellofemoral joint study; rotational study of lower limbs, with visual fields in hips, knees, and ankles; extremities externally rotated in 15 degrees.

-- Evaluation of the study:
The most relevant morphological findings are:
- Bone lesions (Figure 17)
- Joint space (Figure 18)
- Presence of articular effusion (Figure 19)
- Changes in the retinaculum (Figure 20)
- Presence of osteophytes due to traction forces (Figure 21).
- Evidence of intra-articular bodies, popliteal mass or post-traumatic or postoperative deformation (Figures 22-24).
Figure 17. Axial CT reconstruction: patellar luxation with osteochondral fracture of the medial facet and free intraarticular body.

Figure 18. Axial CT reconstruction: normal patellofemoral joint space.
Figure 19. Joint effusion on CT axial reconstruction with bone window and soft tissues.

Figure 20. Reduced Traumatic patellar dislocation, medial retinacular rupture is observed on axial CT reconstruction and MRI, axial PFDS.

Figure 21. Osteophytes by traction in lateral and medial patellar facet, axial CT reconstruction.
**Figure 22.** Distension of gastrocnemius-semimembranosus bursa with popliteal cyst formation (arrows), axial CT reconstruction in bone window (a) and soft tissues (b).

**Figure 23.** Presence of intra-articular bone body (arrow) in posterior femorotibial space, axial TC reconstruction.
Figure 24. Osteochondral lesion in the patellar apex (arrows), with some small cystoid images on axial CT reconstruction (a) and MRI, axial PFDS (b).

Figure 25. Dejour's classification of trochlear dysplasia with knees in extension on CT scan: Type A: flat trochlea with an angle > 140 °; type B: flat or convex trochlea; type C: hypoplasia of the medial femoral condyle; type D: hypoplasia of medial femoral condyle with vertical bone union between the two patellar facets.

Additionally, a set of measurements and classifications, already described in the literature, clinically relevant for the study of PFd are proposed:

- *Patella types according to Wiberg classification*: with knees in extension (same as described in plain radiology).

- *Trochlear angle with knees in extension*: The existence of trochlear dysplasia is determined if angle is > 140 ° (the same as described in plain x-rays).
- **Trochlear dysplasia with knees in extension**: the degree of dysplasia is determined according to Dejour’s classification for CT scans (12) (Figure 25).

- **Patellar height with the knees flexed at 20°**: To determine patella in normal, high, or low position (Same as described in plain x-rays) (11,24) (Figure 26, 27). It is important to note that these measurements described for plain x-rays may be reproduced for CT exams, since they permit reconstructions in 3 planes; in this case measurement of patellar height is performed on sagittal reconstruction.

- **Supratrochlear spur with knees flexed 20°, as described by Dejour** (6). The presence or absence of a supratrochlear prominence is determined on sagittal reconstruction (same as described in plain x-rays).

- **Patellar congruence at flexion of 20°, according to Merchant** (25). Measurement is carried out as explained above concerning plain x-rays and existence of lateral or medial patellar subluxation is determined (Figure 28).

- **Patellofemoral angle in 20° of flexion, as described by Laurin** (17). A horizontal line passing along the most anterior aspect of both femoral condyles is drawn, along with a horizontal line passing through the posterior aspect of the lateral facet, to determine if lines open laterally indicating normal joints, or open medially or run parallel, denoting a pathological condition.

- **ITS-ATT Distance in extension**, according to Dejour (6).

- **External patellar tilt in extension**, according to Dejour (6) (Figure 30).
Figure 26. Insall-Salvati ratio on sagittal CT view; patient with degenerative changes and chondrocalcinosis.

Figure 27. Caton on CT sagittal reconstruction, same patient as in Figure 26.
Figure 28. Congruence angle as described by Merchant, with knees flexed at 20 degrees.

Figure 29. Laurin patellofemoral angle of 20 degrees of flexion, pathological: parallel and opens laterally.
Iwano classification for presence of patellofemoral osteoarthritis is included, since lower extremity alignment abnormalities along with other factors, such as trochlear dysplasia, tibial malrotation, direction / magnitude of the load applied to quadriceps muscle, etc., can play a role in the development of the alteration, from condromalasia to advanced-stage osteoarthritis (26).

Osteoarthritis in extension, according to Iwano (27). Evidence of degenerative joint disease is determined, by classifying it into the following grades:

Grade I: Remodeling Phenomena.

Grade II: Reduction in the amplitude of joint space, space > 3mm.

Grade III: Decrease in the amplitude of joint space, space < 3mm.

Grade IV: bone-to-bone contact.

The rotational study of lower limbs in extension, according to Ballester, is carried out and following measurements are discussed:

- Acetabular anteversion: the cut is chosen at the level of femoral heads to draw a horizontal line connecting the center of the femoral heads, then a line perpendicular to
it, passing through the lateral margin of the posterior acetabular wall and a last line is drawn to join the lateral margins of the anterior and posterior acetabular walls. The angle formed in the intersection of the perpendicular line and the line joining the acetabular walls corresponds to the angle of femoral anteversion \(^{(28)}\). The normal value is 15 ± 5 degrees \(^{(11)}\) (Figure 31) This measurement is not currently included in our protocol because studies to date suggest that acetabular version is not a common factor in rotational problems.

• **Femoral anteversion:** FAV is the angle formed by the axis of femoral neck -head center and the posterior bicondylar line. Sometimes it may be impossible to draw a line passing through the axis of the femoral neck and through the center of the femoral head also, so two cuts have to be made, one showing the head and neck, which are overlapped to draw the axis of the neck. The posterior bicondylar axis is obtained by drawing a tangent on the posterior aspect of both femoral condyles. It is important that in this cut the intercondylar notch is not exceeding one third of the height of the condylar region, from an anteroposterior perspective. The normal value is defined as 14 ± 7 ° \(^{(23)}\) (Figure 32).

• **External tibial torsion:** Measured between the posterior tibial axis and the bimalleolar axis. The posterior tibial axis is drawn as a line parallel to the posterior margin of the proximal tibia. This cut should be made as close as possible to the articular surface, since the tibial torsion occurs proximal to the ATT; the bimalleolar axis is drawn between the tibial and fibular malleoli. The normal value is defined as 25 ± 7 ° \(^{(23)}\). Notably, independent of the measured values, all difference between both lower limbs more than 8 ° should be considered as pathological \(^{(23)}\) (Figure 33).
Figure 31. Measurement of AA on CT scan.

Figure 32. Measurement of AVF on CT scan.
This information is systematized in two tables, dividing information in PFJ local changes and rotational abnormalities of the lower extremities (Table II).

**Table II.** Scheme of measure systematization in imaging study report of patients with PFD.

Finally, we try to reach a diagnostic impression to conclude what are the key points in the PFD, mainly the presence or absence of trochlear dysplasia and patellar position: subluxation, subluxation plus patellar tilt or just tilt. These are crucial point if we consider that these groups of patients have different symptoms and different therapeutic approaches (2).

The report also adds, if any, relevant associated morphological findings and specific alterations of measurements described above. Importantly, isolated altered measurements do not constitute a diagnosis; asymptomatic patients have been described with altered measurements and *vice versa*, so measurements should be assessed in the clinical context of each individual patient. All this data should be clearly registered in each radiological report.

**Conclusions**

Pathology of the PFJ is an issue not yet clarified from the clinical or radiological...
viewpoint since there are multiple anatomical and dynamic factors involved. Radiologic studies mainly provide analysis of static anatomical factors, both local and rotational, despite the latter have not yet been fully understood. This review attempts to propose the radiological study to be performed on patients with PFD, by determining the relevant points to be addressed with the different radiologic techniques. We also propose a second-line tomographic study of PFJ, which additionally includes a rotational study of the lower limbs. We also suggest the points to be considered and the most relevant measurements to be carried out from the radiological-clinical point of view, systematizing and registering the information available to date in a report sheet. We must always remember that the assessment of imaging studies should be made in the clinical context of each individual patient.

References

13. Lancourt JE, Cristini JA. Patella alta and patella infera.


