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Patellofemoral malalignment and chondral damage: current concepts

CLAUDIO MAZZOLA, DAVIDE MANTOVANI

Joint Surgery Section, EO Galliera, Genova, Italy

Abstract

Patellofemoral disorders can be classified according to specific criteria, and the most well-known classification systems are Insall's classification and Merchant's classification.
In this work, after completion of an in-depth literature review, we will analyze the most frequent patellofemoral pathologies with the aim of determining the correct clinical-diagnostic-therapeutic course.
Pathologies of greater clinical frequency will be examined in detail to provide the most relevant didactic scope. We will therefore address the following pathologies: excessive lateral patellar compression syndrome; patellar dislocations and subluxations; patellar chondromalacia; and patellofemoral osteoarthritis.

Key Words: patellofemoral, cartilage, chondral lesions, treatments.

The vast field of patellofemoral (PF) disorders encompasses many different problems that tend to arise from adolescence onwards.
The study of the patellofemoral (PF) joint in orthopedic research reflects the huge variability of the pathophysiological context due to complex anatomy and biomechanics of the joint. Indeed, pathophysiology of the PF joint is very complex and in most cases is regulated by many factors.

Corresponding Author:
Claudio Mazzola, MD
Joint Surgery Section, EO Galliera
Corso Mentana 10
16100 Genova, Italy
Phone: +39 010-5634699
E-mail: guimazz@alice.it.

There are two well-known classification systems for PF disorders, namely Insall's classification (1) and Merchant's classification (2).
According to Insall's classification (1), PF disorders can be divided into three groups of problems according to the involvement of articular cartilage:
- peripatellar disorders such as bursitis, tendonitis, overuse injury syndromes, reflex sympathetic dystrophy (RSD), and patellar abnormalities with generally normal cartilage;
- malalignment syndrome and synovial folds, with variable chondral damage;
- chondromalacia, osteoarthritis (OA), osteochondral fractures, and osteochondritis dissecans, with presence of chondral damage.

There are five main identifiable groups according to Merchant's classification (2), namely:
- **Injuries**, i.e. acute injuries (bruises, fractures, dislocations, tendon ruptures), repeated injuries (overuse syndromes), and late effects of injuries (fibrous chondromalacia, OA, RSD);
- **PF dysplasia** (lateral patellar compression syndrome, chronic patellar subluxation, recurrent patellar dislocation, and chronic patellar dislocation);
- **Idiopathic patellar chondromalacia**;
- **Osteochondritis dissecans;**
- **Synovial folds**.

The above groups mainly serve to highlight the complex pathophysiology of the PF joint. For this reason it is essential to undergo an accurate diagnosis to undertake proper treatment.

Lateral patellar compression syndrome
This is a syndrome characterized by patellar pain exacerbated by knee flexion, without instability. The pain is typically dull and localized, and exacerbated by activities that stress the PF joint, such as stair climbing, squatting, and sitting for long periods with flexed

knee. Malalignment of the lower limbs seems to be the common denominator of this group of patients, including an increase of Q angle and a retraction of the lateral retinaculum (**Fig. 1**). These patients often report swelling, but the occurrence of joint effusion is uncommon. Effusions are more frequently associated with chondral damage, due to possible formation of debris, which cause synovial inflammation. Patients can refer some locking or catching; these symptoms may be caused by a temporary quadriceps inhibition, secondary to pain, or by some chondral irregularities which prevent the correct patellar tracking during knee extension. Often, differential diagnosis between knee locking due to lateral patellar compression syndrome (LPCS) and that due to patellar instability is very challenging. However, in patients with LPCS, knee locking is generally described as a secondary symptom and actual episodes of patellar instability followed by considerable swelling that persists for several days are absent. The apprehension test is negative and there are only minimal patellar tracking abnormalities. The patient should be evaluated in different conditions: standing, while ambulating, when sitting, and in supine decubitus. Standing position is useful to appreciate patellar strabismus. Ambulation can reveal foot pronation; correction of this alteration, if present, can determine an effect on the extensor mechanism. The patient is asked to do a semi-squat and to maintain the position for short periods, which usually generates pain. The complete squat position, with the patient sitting on his heels with relaxed quadriceps, is generally less painful. The patient is then evaluated in a sitting position and asked to perform a knee extension, during which patellar tracking is observed. During the arc of movement particular attention should be paid to the possible occurrence of a moderate lateral patellar displacement or tilt in full extension and flexion. This patellar tilt is normally horizontal and reaches up to 5 degrees downwards or laterally. In supine position it is frequent to observe an increase of the Q angle (3). The assessment of retraction of the lateral retinaculum is essential in LPCS. The examiner should be able to lift the lateral edge of the patella until its transverse axis is tilted above the horizontal plane (passive patellar tilt test). With the knee at 20-30 degrees of flexion, it should be possible to displace the patella in a medial direction to more than a quarter of its width. If these tests are positive, retraction of the lateral retinaculum is confirmed (4). The clinical examination concludes with the patellar compression test.

Fig. 1. CT scan showing lateral patellar tilt secondary to retraction of the lateral retinaculum.

The standard radiographic projections, such as: anterior-posterior (AP), lateral, and axial (45-degrees of axial bending) views do not provide diagnostic information in case of LPCS (5). Computed tomography (CT) is more accurate and thus strongly recommended. Using a well-defined reference line, tangential to the rear side of the femoral condyles and the suppression of bone overlay allows the identification of even small abnormalities. Schultzer et al. (6), using mid-patella CT scans at 0, 10, 20, and 30 degrees, found that the patella in normal subjects centers on the trochlea at 10 degrees of flexion. In addition, the angle between the tangent to the rear side of the femoral condyles and the tangent to the lateral patellar facet (patellar tilt angle) appeared constantly opened laterally and never less than 8 degrees. The authors defined patellar subluxation when congruence angle was still positive over 10 degrees of flexion, and patellar tilt when the tilt angle was less than 8 degrees in the early 30 degrees of flexion.
Two hypotheses were formulated regarding the pathogenesis of pain in malalignment syndromes, namely: a lateral patellar bone overload and excessive tension of the lateral retinaculum. The pain threshold of the subchondral bone may be exceeded even when the carti-

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lage is intact, for example in cases of stress or excessive force or in cases where normal forces are applied along abnormal directions (7, 8). For this reason, in case of malalignment, it is believed that the lateralization of PF tracking and a medial-to-lateral tangential overload of the patella are the main causes of pain, but these are rarely the cause of chondromalacia (9). Therefore, both an excessive lateral overload of the patellar surface and an excessive tension of the lateral retinaculum can contribute to the onset of pain in LPCS.

Regarding treatment, rest is fundamental when the onset of symptoms is acute. Subsequently, quadriceps strengthening is probably the most essential component of standard treatment, particularly strengthening of the vastus medialis oblique (VMO) can lead to improvement. Then, isometric exercises should be introduced, followed by isotonic exercises with short angles (10); the McConnell protocol is valid and recommended (11).

Surgical treatment can be undertaken in knees with persistent disabling symptoms that do not improve after an appropriate rehabilitation program. In these knees the lateral retinaculum release (LRR) is indicated. This procedure should only be performed in very selected cases. An ideal candidate for LRR should show a reduction in the extent of medial dislocation, and CT axial images should show a patellar tilt with no or mild subluxation (12). The evaluation and comparison of the results reported in the literature on lateral retinacular release (LRR) is difficult. Most authors do not regularly use classification systems and therefore it is unclear whether results are comparable. Results are deemed to be satisfactory in about 73% of the cases. The evaluation of preoperative factors is essential, with the most important factor probably being demonstration of patellar maltracking and an excessively retracted lateral retinaculum (13). During the operation, the arthroscopic evidence of patellar maltracking and the presence of a thickened and retracted lateral retinaculum are predictors of positive results. Unsatisfactory results were associated with incomplete release or scarring of the lateral retinaculum during the healing phase (14). It appears that simple chondromalacia or mild fibrillation do not affect the results, but it was noticed that deep fissuring or subchondral bone exposure, with possible alterations of the trochlear surface, lead to unsatisfactory results (15). Another important factor that can determine unsatisfactory results is the lack of rehabilitation of the quadriceps and VMO.

Patellar dislocation and subluxation

Patellar dislocations and subluxations are considered clinical manifestations of patellar instability; these two conditions, whilst similar in nature, differ in magnitude. Subluxation is defined as an abnormality of patellar tracking with preservation of the relationship between the patella and the trochlea. Dislocation is the complete loss of relationship between the patella and the trochlea. In addition, the patella may present a lateralization of tracking without episodes of instability (chronic patellar subluxation).

Acute patellar dislocation

The diagnosis of acute patellar dislocation applies to those knees that are examined at the first episode of dislocation. The patient usually reports a twisting movement of the limb, followed by a popping sound, with the knee giving way, resulting in the patient falling to the ground. Swelling appears almost immediately, and if the patient has noticed abnormal patellar dislocation, the diagnosis is obvious. Usually the most frequent mechanism is represented by the foot fixed to the ground, internal rotation of the femur with respect to the tibia and contraction of the quadriceps. In this relative position of the two long bones, there is an increase of the Q angle and therefore, quadriceps contraction draws the patella laterally out of the trochlea. The same mechanism has also been described in baseball pitchers (16) (**Fig. 2**).

Physical examination is most efficiently carried out following arthrocentesis. Attempts to laterally dislocate the patella are frustrated by apprehension. Differential diagnosis should take into consideration the rupture of the anterior cruciate ligament or of the quadriceps or patellar tendons. The latter condition can be ruled out if the patient is able to lift the extended limb; if the patient is unable to perform this movement and if an appreciable gap is noted upon palpation, proximally or distally to the patella, the diagnosis will be confirmed. In the case of suspected acute patellar dislocation, examination of the contralateral knee is helpful. The evidence of a patella malalignment can further facilitate the diagnosis.

All patients with suspected acute patellar dislocation must undergo a routine radiographic examination. The presence of osteochondral fractures of the medial patellar facet or lateral femoral condyle can be excluded by using oblique projections and the intercondylar notch view (17). Osteochondral fractures are associat-

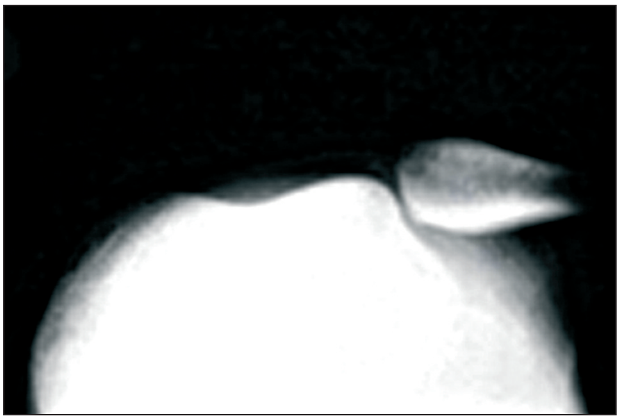

Fig. 2. Radiographic axial view showing acute lateral dislocation of the patella.

ed with acute patellar dislocation in about 5% of the cases (18). Magnetic Resonance (MR) is very useful to assess the extent of damage after acute patellar dislocation. It has been estimated that avulsion of the femoral insertion of the medial patellofemoral ligament (MPFL) occurs in 87% of cases, retraction of the VMO at varying degrees in 78% of cases, osteochondral lesions of the lateral femoral condyle in 87% of cases, and osteochondral lesions of the medial facet of the patella in 30% of cases (**Fig. 3**). This agrees with the study by Conlan et al. (19), who demonstrated that MPFL is the primary restraint which opposes the lateral dislocation of the patella, responsible for 53% of the braking force, followed by the patello-meniscal ligament, which contributes for 22%.

Cofield and Bryan (20) recommended immediate selective repair in patients with anatomical variants, which would otherwise lead to recurrence in high level athletes and in knees with displaced articular fractures. According to Larsen and Lauridsen (21), non-traumatic dislocations were most frequently found in women (57%) compared to men (32%). Younger patients showed an increased prevalence of predisposing factors, which were present in 84% of subjects under the age of 14 years, in 69% of those between 15 and 19 years and in 41% of those between 20 and 29 years. According to these findings, re-dislocation was most likely in younger patients (age <20 years). According to Hawkins et al. (22), surgical treatment would be recommended in those knees with a combination of predisposing factors, including *genu valgum*, an increase in the Q angle, patella alta or an abnormal patellar morphology. In view of the low success rate of conservative treatments of acute patellar dislocation, some authors have suggested the use of surgery in cases of anatomical abnormalities or osteochondral fractures (23). It seems that the recurrence rate is reduced when the intervention is carried out in the acute stage compared to nonsurgical treatments. However, our preferred treatment for acute dislocations is still conservative. Surgery in any case will never bring the knee to the *status quo ante* in 100% of cases and surgical complications are always possible. Therefore, our preferred treatment is immobilization for 4 weeks in a brace. Then quadriceps strengthening should be started as soon as possible, followed by partial weight-bearing based on tolerance. After one month, the improved muscle strength will consent gradual removal of the brace. There are exceptions to the conservative treatment; the most common is when there is radiographic evidence of an osteochondral fracture.

Chronic patellar subluxation

This category includes patients with knees pain, in which the axial radiographic views and CT scans reveal a lateral displacement of the patella. These cases can be interpreted as an intermediate degree of PF malalignment between LPCS and recurrent instability. Dejour (24) observed that this pattern is present in about 20% of cases with patellar pain and called it "*instabilités*

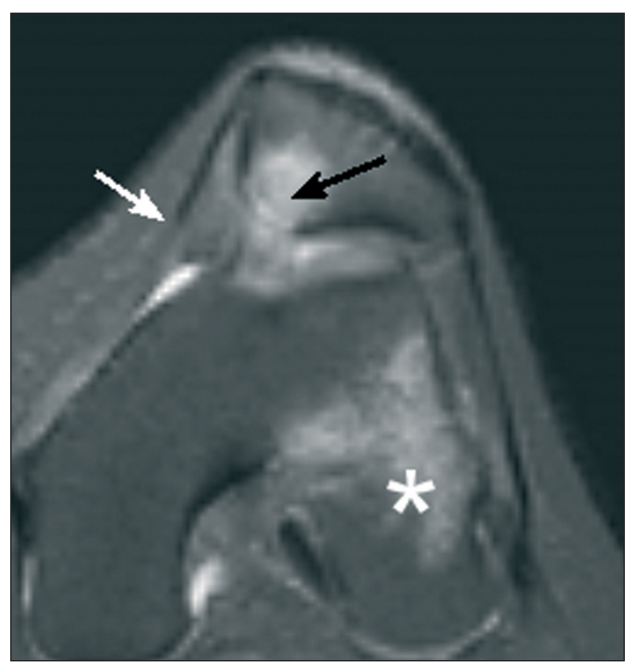

Fig. 3. MR scan showing acute dislocation of the patella after reduction. Osteochondral lesion of the medial facet of the patella (black arrow), avulsion of the femoral insertion of the medial patellofemoral ligament (white arrow), and bone bruise of the lateral femoral condyle (asterisk) can be seen.

rotuliennes potentielles". The symptoms are similar to those described for LPCS and the initial treatment is nonoperative. The patients usually describe an initial episode of patellar dislocation treated conservatively. After this first episode, similar episodes of instability following modest traumas are referred. In the physical examination it is important to assess the patient in a sitting position. The patient is asked to extend his leg and usually patellar subluxate in extension. In severe cases the subluxation can be sudden and painful, and can limit full extension. With the patient in a supine position, the Q angle can be examined with the knee flexed at 90°, when the patella comes down into the trochlea. The most sensitive and specific test is the apprehension test.
Conventional radiographs and CT are used to detect bone abnormalities, such as: patella alta, trochlear dysplasia, lateral subluxation and tilt of the patella, a lateral position of the tibial tuberosity and an excessive femoral anteversion. Axial views at 30, 45, or 20° of flexion are usually sufficient to highlight trochlea anomalies and patella malalignment. According to Dejour (24), in knees with recurrent dislocations, the deepest point of the trochlea is anterior compared to the same point of normal knees, if the anterior cortex of the femur is used as a reference. This means that the flattening of the trochlea, in knees with recurrent dislocation, is due to a reduction in the depth of the trochlea and not to a reduction in height of the lateral trochlea. Runow (25) observed that both intrinsic and extrinsic factors may contribute to recurrent dislocation of the patella, with trauma being an extrinsic factor. The anatomical abnormalities and generalized ligament laxity are intrinsic factors. It is also important to highlight that moderate trauma, with direct and indirect force on the patella, is identifiable as cause of dislocation in 55% of cases. Therefore, it is unlikely that a trauma causes patellar dislocation in a completely normal knee. The treatment of recurrent instability envisages a nonsurgical intervention relying on quadriceps and VMO strengthening and stretching of the lateral soft tissues. In the case of failure of conservative treatment, LRR has been suggested with a rate of satisfactory results reported in the literature from 30 to 100%. Another important intervention is the Insall's proximal realignment (8). This is a rearrangement of the quadriceps insertions on the patella and its purpose is to modify the line of action of the quadriceps muscle. The quadriceps angle is not changed, nor is the length of the patellar tendon, but realignment corrects the adverse effects of the patellofemoral incongruence. Results of this procedure vary depending on the chondral lesions observed, from excellent and good in 93% of cases with grade-I chondral lesions up to 33% in case of grade-III lesions.
Distal realigment procedures are characterized by the medial and/or distal transfer of the tibial tuberosity or the tibial insertion of the patellar tendon, thus reducing the magnitude of the Q angle and correcting the excessive height of the patella.
Distal realignments can be combined with proximal soft tissue procedures. The best known interventions of this type are the techniques of Elmslie-Trillat (26) and Hughston (27), which have proved effective in preventing recurrence of dislocation. However, lateralization of the patella in the end-range of extension was observed in 30-57% of cases, and the apprehension test remained positive in 14-31% of cases.

Chronic patella dislocation

The category of chronic patella dislocations includes knees with patellae which dislocate laterally whenever the knee flexes, returning towards the midline during extension. Very often disease is unrecognized until the age of 4-5 years. The most frequent clinical situation is one where the parents notice that the child has difficulty in standing from a sitting or squatting position. The two goals of surgical treatment are realignment of the patella and lengthening of the quadriceps tendon.

Chondromalacia Patellae and patellofemoral osteoarthritis

The first description of cartilage "malacia" was provided by Buedinger (28). He described fissures that were thought to be secondary to a traumatic event. The definition "chondromalacia" is attributed to Aleman (29). Fissures are rare before the age of 20 years but gradually become more common after the second decade of life, to affect all knees after the fourth decade. According to the author it is rare to observe a normal knee after 50 years.
Ficat et al. (30) provided a description of chondromalacic alterations associated with known patellofemoral disorders, such as a lateral patellar tilt around the central ridge secondary to retraction of the lateral retinaculum. The critical zone is that situated around the central ridge of the patella, with a certain extension to the lateral facet. Insall et al. (31) found that the most frequent location of chondromalacia (71%) had an elliptical area with the major axis lying transverse, bridging

over the central part of the patella, with the upper and lower third of the articular surface almost always spared. However, it seems that patellar pain is be secondary to another factor. The deformation of the articular cartilage can result in an abnormal loading of the subchondral bone causing pain, even in the absence of chondral lesions.

Regardless of the cause, the appearance of a degeneration of the patellar cartilage evolves from a softening stage followed by fissuring and fibrillation, up to subchondral bone exposure.

Histological characteristics of chondromalacia vary depending on the stage of the disease. In knees with closed chondromalacia, electron microscopy examination highlights changes in the three chondral components: cells (chondrocytes), collagen and extracellular matrix (ECM); collagen fibers show a loss of their usual orientation; ECM show an increase in volume; and the number of chondrocytes is slightly reduced with signs of activation and degeneration. Moreover, chondrocytes tend to cluster in the surface and transitional area. Optical microscopy examination of the lesions in open chondromalacia reveals a clear fibrillation of the surface. Changes of cartilage components are more degenerative in nature. Chondrocytes are reduced in number and show a clear trend to grouping. The ECM is disrupted and assumes dyes in an inhomogeneous manner. Therefore, the earliest changes of chondromalacia affect the transitional zone, while the tangential reticulum of surface fibers is spared. The cartilage seems to react to the increase in the load and to the functional requests by means of an increase in the chondrocyte activity. If the functional requests exceed the chondrocyte potential , a greater number of cells die. We believe that the cause of patellar chondromalacia in knees with PF malalignment is the appearance of high compressive forces that act on the lateral facet associated with shear forces in the central ridge area, which develop to oppose patella dislocation. We recall that Wiberg, in his classic work, described three different types of patellar morphology. He defined type III as having the most pronounced dysplasia, with a clear predominance of the lateral facet and a smaller convex medial facet. Nevertheless, he could not prove an association between patella type III and chondromalacia. The same observation was made by Outerbridge (32). Therefore, it seems that the morphology of the patella cannot be considered an etiological factor of chondromalacia.

It is known that chondromalacia can develop after surgery on the knee. For example, in the anterior cruciate ligament reconstructions, about a quarter of patients develop chondromalacia. The biochemical events that lead to pathophysiology of chondromalacia was investigated by Christman (33). He hypothesized that trauma or repeated micro-traumas can initiate the chondral degenerative process by an increased release of arachidonic acid, a precursor of prostaglandins. Synovitis leads to the production of enzymes by the synovial membrane, which in turn attack the cartilage, triggering a vicious cycle. Administration of non-steroidal anti-inflammatory drugs can reduce the synthesis of prostaglandins from arachidonic acid and thereby reduce the chondral softening and synovitis.

PF osteoarthritis preferentially affects the aspect of the PF joint in most cases. Axial radiographic projections show narrowing of the joint line, osteophytosis of the lateral margin of the patella and trochlea, subchondral sclerosis of the lateral facet and sometimes the formation of geodes. PF osteoarthritis is often associated with degenerative changes of the medial or lateral femorotibial joint. Isolated involvement of the medial aspect of the PF joint is rare.

Osteoarthritis can be regarded as the final stage of progression of chondromalacia. According to Ficat et al. (30), LPCS is the most frequent cause of patellofemoral osteoarthritis. When conservative treatment fails, surgical treatment can then be undertaken.

Interventions for chondromalacia and osteoarthritis can be divided into two categories, namely: those that aim to relieve the loading stress of the patellofemoral joint by means of realignment or restoration of the kinematics of the extensor mechanism and those that aim to directly address the chondral damage. The first category includes interventions such as LRR, proximal and distal realignment and elevation of the tibial tuberosity. The rationale for the choice of these interventions is the consideration that PF osteoarthritis or chondromalacia constitute an epiphenomenon and the correction of the biomechanical abnormality that support them should prevent the progression of degenerative changes. The second category of treatments includes chondral shaving, excision, perforation or abrasion of the subchondral bone, cartilage grafts, bone grafts or replacement. These interventions should be rendered as a single surgical act in selected cases, in which underlying biomechanical abnormalities are not identified.

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