Patellofemoral Pain and Instability

Etiology, Diagnosis and Management

Beth E. Shubin Stein
Sabrina M. Strickland
Editors

Springer

Patellofemoral Pain and Instability

Beth E. Shubin Stein • Sabrina M. Strickland
Editors

Patellofemoral Pain and Instability

Etiology, Diagnosis and Management

Springer

Editors
Beth E. Shubin Stein, MD
Department of Orthopedic Surgery
Hospital for Special Surgery
New York, NY, USA

Sabrina M. Strickland, MD
Hospital for Special Surgery
New York, NY, USA

ISBN 978-3-319-97639-6 ISBN 978-3-319-97640-2 (eBook)
https://doi.org/10.1007/978-3-319-97640-2

Library of Congress Control Number: 2018964721

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

Patellofemoral Pain and Instability: Etiology, Diagnosis and Management is a clear and concise text intended to be useful for all health care professionals caring for patients with patellofemoral dysfunction.

Interest in patellofemoral disorders has increased in recent years as new studies and new technologies have emerged, helping guide us in terms of diagnosis and best practices in treatment. Although many patellofemoral disorders have historically been considered complex and difficult to treat, use of the most up-to-date research and practical guidelines has helped simplify the diagnosis and the treatment options available. Understanding the etiology and evolving high-level literature on patellofemoral instability, as well as the modern treatment options for patients with patellofemoral pain and arthritis, is essential to diagnosing and treating the broad spectrum of patellofemoral disease.

The patellofemoral joint is unique in every patient. However, the basic principles of this joint and its form and function can help us understand the underlying etiology of the pathology as well as the appropriate treatment options to decrease pain and restore function.

This book presents best practices in diagnosis and treatment of patients with what have previously been considered to be complex patellofemoral disorders. We know this book will be an invaluable and practical guide to all physicians and medical professionals caring for patients with patellofemoral disorders.

New York, NY, USA

Beth E. Shubin Stein, MD
Sabrina M. Strickland, MD

Contents

Part I Patellofemoral Pain

1 PF Pain in the Skeletally Immature Patient: Diagnosis and Management 3
Meghan J. Price, Joseph Moloney, and Daniel W. Green

2 Anterior Knee Pain 27
Alex A. Johnson and Miho J. Tanaka

3 Malalignment and Overload Syndromes 53
Brandon J. Erickson and Andreas H. Gomoll

4 Patellofemoral Arthritis 65
Dean Wang, Sabrina M. Strickland, and Beth E. Shubin Stein

5 Imaging in Patellofemoral Pain 85
Vivek Kalia and Douglas N. Mintz

Part II Patellofemoral Instability

6 Instability in the Skeletally Immature Patient 119
Lauren H. Redler and Christopher S. Ahmad

7 Acute Patellar Dislocation (First-Time Dislocator) 141
Jacqueline Munch Brady

8 Recurrent Patellar Instability 149
Robin West, Ryan S. Murray, and Daniel M. Dean

9 Patellofemoral Instability Surgery Complications: How to Avoid Them 171
Michael S. Laidlaw, David R. Diduch, and Brian C. Werner

10 Imaging in Patellofemoral Instability 193
Vivek Kalia and Douglas N. Mintz

Index 211

Contributors

Christopher S. Ahmad, MD Columbia University Medical Center, Department of Orthopedic Surgery, New York, NY, USA

Jacqueline Munch Brady, MD Department of Orthopaedics and Rehabilitation, Oregon Health and Science University, Portland, OR, USA

Daniel M. Dean, MD Department of Orthopedic Surgery, Georgetown University Hospital, Washington, DC, USA

David R. Diduch, MD Department of Orthopedic Surgery, Universtiy of Virginia, Charlottesville, VA, USA

Brandon J. Erickson, MD Hospital for Special Surgery, Division of Sports and Shoulder, New York, NY, USA

Andreas H. Gomoll, MD Hospital for Special Surgery, Division of Sports and Shoulder, New York, NY, USA

Daniel W. Green, MD, MS, FAAP, FACS Hospital for Special Surgery, New York, NY, USA

Alex A. Johnson, MD Department of Orthopedic Surgery, The Johns Hopkins University, Baltimore, MD, USA

Vivek Kalia, MD, MPH, MS Hospital for Special Surgery, New York, NY, USA

Michael S. Laidlaw, MD Department of Orthopedic Surgery, Universtiy of Virginia, Charlottesville, VA, USA

Douglas N. Mintz, MD Hospital for Special Surgery, New York, NY, USA

Joseph Moloney, PT, MS, SCS, CSCS Hospital for Special Surgery, New York, NY, USA

Ryan S. Murray, MD Department of Orthopedic Surgery, Georgetown University Hospital, Washington, DC, USA

Meghan J. Price, BS Duke University School of Medicine, Durham, NC, USA

Lauren H. Redler, MD Columbia University Medical Center, Department of Orthopedic Surgery, New York, NY, USA

Beth E. Shubin Stein, MD Sports Medicine and Shoulder Service, Hospital for Special Surgery, New York, NY, USA

Sabrina M. Strickland, MD Sports Medicine and Shoulder Service, Hospital for Special Surgery, New York, NY, USA

Miho J. Tanaka, MD Department of Orthopedic Surgery, The Johns Hopkins University, Baltimore, MD, USA

Dean Wang, MD Sports Medicine and Shoulder Service, Hospital for Special Surgery, New York, NY, USA

Brian C. Werner, MD Department of Orthopedic Surgery, Universtiy of Virginia, Charlottesville, VA, USA

Robin West, MD Inova Sports Medicine, Georgetown University Medical Center, Washington, DC, USA

Virginia Commonwealth University School of Medicine, Richmond, VA, USA

Part I
Patellofemoral Pain

Chapter 1
PF Pain in the Skeletally Immature Patient: Diagnosis and Management

Meghan J. Price, Joseph Moloney, and Daniel W. Green

Introduction

The focus of this chapter is on the differential diagnoses of anterior patellofemoral knee pain in children and adolescents. The discrete causes of anterior knee pain that we discuss are listed in Table 1.1; however, many patients will present with anterior knee pain without a discrete diagnosis. These are the patients who fall into the broader diagnostic categories of anterior knee pain in adolescents and patellofemoral pain syndrome. Historically, these conditions have been referred to in the literature by the overarching diagnosis of chondromalacia. At a certain point, chondromalacia was so commonly associated with anterior knee pain that it was the accepted clinical diagnosis for anterior patellofemoral pain [1, 2]. However, now diagnosis of chondromalacia of the patella requires radiographic or arthroscopic proof of soft or damaged articular cartilage. This distinction has led to more effective and specific treatment and physical therapy plans for the causes of patellofemoral knee pain that are unrelated to cartilage damage.

This chapter will review common diagnoses of anterior knee pain in children and adolescents. Patellofemoral pain secondary to instability and malalignment will be discussed elsewhere in this textbook.

M. J. Price
Duke University School of Medicine, Durham, NC, USA

J. Moloney · D. W. Green (✉)
Hospital for Special Surgery, New York, NY, USA
e-mail: greend@hss.edu

B. E. Shubin Stein, S. M. Strickland (eds.), *Patellofemoral Pain and Instability*,
https://doi.org/10.1007/978-3-319-97640-2_1

Table 1.1 List of differential diagnoses for pediatric anterior patellofemoral knee pain

Anterior knee pain in adolescents
Patellofemoral pain syndrome (PFPS)
Osgood-Schlatter's disease
Tibial tubercle fracture
Sinding-Larsen-Johansson syndrome
Patellar sleeve fracture
Bipartite patella
Trochlear JOCD
Patellar JOCD
Hoffa's fat pad impingement
Plica syndrome
Chondromalacia of the patella
Prepatellar bursitis
Patellar tendonitis
Patellar stress fracture
Patellofemoral maltracking/malalignment
Patellofemoral instability
Pain syndromes
Avascular necrosis
Bone bruise/bone contusion
Inflammatory arthritis
Tumor

Anterior Knee Pain of the Adolescent

When young adolescents present with anterior patellofemoral knee pain that cannot be given a discrete diagnosis, we often use the term adolescent anterior knee pain. This condition typically occurs in adolescents who are active and participate in sports. It is considered an overuse injury that often results from a training routine that does not include sufficient strengthening and stabilizing routines for the knee and the surrounding hip and core muscles.

Patients with anterior knee pain of the adolescent typically experience a dull, achy pain that presents over time and worsens with activities, particularly those that involve flexion and extension such as jumping, squatting, sprinting, etc. other typical symptoms are pain with repetitive bending of the knee, when climbing stairs or after prolonged periods of sitting. Physical examination should include an evaluation of lower leg alignment, kneecap position, tightness of the heel cord, flexibility of the feet, knee stability, hip rotation, range of motion (ROM) of knees and hips, kneecap palpation, and strength, flexibility, firmness, and tone of the quadriceps and hamstrings. Plain radiographs and MRIs can help exclude a more concrete diagnosis; however, radiography will typically appear normal in patients with anterior knee pain of the adolescent.

In most cases, temporary activity modification, short-term use of nonsteroidal anti-inflammatory drugs (NSAIDs) and ice to address pain, and a strengthening and

flexibility routine will be successful in providing relief. Patients can work with their physicians to establish an activity regimen that limits the duration and intensity of athletic activities and rather focuses on low-impact sports such as biking and swimming. In addition, a physical therapy regimen that includes exercises to help increase hamstring flexibility and strength of the core and hip muscles supporting the knee is important. Trainers and physical therapists can also help address any issues in exercise technique that could be causing this persistent knee pain. It is important that patients develop good exercise habits including wearing proper athletic shoes, warming up thoroughly before practice, stretching before and after physical activity, and establishing a routine which supports hip and core strength.

Patellofemoral Pain Syndrome (PFPS)

We acknowledge that there is significant overlap between anterior knee pain of the adolescent and patellofemoral pain syndrome (PFPS) – so much that some physicians do not distinguish between the two. However, PFPS often comes with the implication of mild patellofemoral instability (without dislocation) and/or patellofemoral overloading (without obvious articular cartilage damage).

Patients with PFPS typically present with pain and stiffness in the front of the knee around the patella. This pain can worsen when climbing stairs, kneeling, squatting, or performing everyday tasks. Patients often report cracking or popping sounds when changing position or climbing stairs and also experience pain during repeated knee bending. PFPS is a non-specific diagnosis that is given when all other differential diagnoses can be ruled out by the appropriate clinical and radiographic exams.

Symptoms are most often relieved with conservative treatment including activity modification, rest, ice, temporary compression, and short-term use of NSAIDs. Patients are advised to decrease the intensity and duration of physical activities and to initiate physical therapy exercises that improve range of motion, strength, and endurance. Core, hip, and quadriceps strength and hamstring flexibility are particularly important as they help optimize patellofemoral tracking.

Osgood-Schlatter's Disease

Osgood-Schlatter's is characterized as a traction apophysitis of the proximal tibial tubercle at the insertion of the patellar tendon. Osgood-Schlatter's was first described in 1903 by Robert Osgood, and its etiology is widely accepted as repetitive strain and chronic avulsion of the secondary ossification center of the tibial tuberosity [3]. The specifics of this etiology have not been widely accepted, but several hypotheses have been presented in the literature. Ogden and Southwick suggested that as the tuberosity matures, if the growing ossification center cannot withstand the forces from the patellar tendon, Osgood-Schlatter's disease avulsion can result in extra

bone migration between the fragments [4]. Lancourt and Cristini proposed that a shorter patellar ligament in children with patella infera could cause increased stress on the secondary ossification center [5]. Pronated feet, genu valgum, internal rotation [6], and increased external tibial rotation [7] have also been associated with Osgood-Schlatter's.

Osgood-Schlatter's typically develops during peak growth (ages 8–12 for girls, 12–15 for boys) with a higher prevalence in athletes (21% of adolescents) than non-athletes (4.5% of adolescents) [8]. Common sports that exacerbate Osgood-Schlatter's include soccer, football, basketball, volleyball, gymnastics, and figure skating as they involve sprinting, cutting, and jumping. These activities result in repetitive patellar tendon strain from the strong pull of the quadriceps muscle. Patients usually present with a gradual onset of pain, tenderness, and swelling at the tibial tubercle. There is often an area of prominence at the tibial tuberosity, and pain intensifies with extension of knee against resistance or squatting with the knee in full flexion. straight leg raise is typically painless [9].

Diagnosis of Osgood-Schlatter's is made by clinical examination; however, radiographs are recommended in unilateral cases to rule out other differential diagnoses. Plain radiographs (lateral view of the knee with leg internally rotated 10–20°) are the most useful radiograph for diagnosis of OSS. Typical findings are irregularity of the apophysis with separation from the tibial tuberosity nearly stages and fragmentation in later stages [10] (Fig. 1.1). While radiographic findings may be difficult to distinguish from normal variation in ossification of the tubercle, the tibial tubercle in OSS may also appear elevated from the shaft and irregular, fragmented, or particularly dense. A superficial ossicle, calcification, or thickening may be seen in the patellar tendon [9]. While magnetic resonance imaging (MRI) is typically more useful for identifying atypical presentations of OSS, Hirano et al.

Fig. 1.1 Lateral radiograph

proposed five stages of classification for typical OSS on MRI: normal, early, progressive, terminal, and healing. [11]. The patient presents with symptoms in the normal and early stage but no inflammation or avulsion on MRI. The progressive stage reveals partial cartilaginous avulsion from the secondary ossification center, and the terminal stage includes the separated ossicles. Osseous healing is evident in the fifth, healing, stage without separated ossicles [11].

It is important to be aware of nondisplaced tibial tubercle fracture as a differential diagnosis. These fractures appear similar to Osgood-Schlatter's on radiograph; however, clinically patients present with severe pain and an inability to do a straight leg raise.

Osgood-Schlatter's is a self-limiting condition with expected recovery in well over 90% of patients [12]. A non-operative treatment plan that includes ice, limitation of activities, NSAIDs, knee protection, and a physical therapy plan for strength and flexibility is recommended. For patients who present with severe pain, stopping physical activity until acute pain subsides is recommended. For patients who present with mild to moderate pain (majority of patients), continued athletic participation in moderation is appropriate. Typically the pre-pain activity level of the patient is reviewed and the overall hours spent doing rigorous sprinting and jumping is decreased. Rest days and flexibility exercises are recommended between episodes of strenuous activity.

The vast majority of symptoms resolve when the proximal tibial growth plate closes. However, in less than 1–2% of patients, pain and tenderness over the tibial tubercle persist. Indications for surgery in these patients include skeletal maturity and a persistence of symptoms with a free fragment/ossicle seen on radiograph [13]. The literature has identified surgical procedures to treat rare cases of Osgood-Schlatter's that remain symptomatic in skeletally mature patients. These procedures typically include excision of the prominent portion of the tibial tubercle via a longitudinal incision in the patellar tendon and excision of the ununited ossicles and cartilaginous pieces [14–18].

Sinding-Larsen-Johansson (SLJ) Syndrome

Sinding-Larsen-Johansson (SLJ) syndrome or overuse of distal patellar apophyseal traction is a painful condition that occurs at the junction of the patellar tendon and the lower margin of the patella. First described independently by both Sinding-Larsen and Johansson, this condition shares many similarities with Osgood-Schlatter's [19, 20]. SLJ is an uncommon cause of anterior PF pain with a reported incidence of about 4.8% [21]. SLJ typically occurs when young rapidly growing adolescents overstrain themselves in activities involving repetitive traction exerted by the patellar tendon on the patella such as sprinting or jumping. The repetitive stress and microtrauma from this traction are thought to be the source of pain [22].

Clinically, patients present between ages 10 and 12 with tenderness and/or swelling at the inferior pole of the patella. Pain is accentuated by resistance to quadriceps

Fig. 1.2 A 12-year-old male who plays squash and runs cross-country competitively presents with ongoing complaints of aching right knee pain for the last 6 months with no history of acute injury. Pain occurs in the distal aspect of his patella. Lateral radiographs demonstrate mild bony changes on the distal pole of the patella consistent with SLJ

contraction and patellar loading during flexion [23, 24]. Patellar tendon thickening and infrapatellar bursitis may also be observed [23]. Typically imaging is not necessary to diagnose SLJ, but plain radiographs of the knee are recommended in unilateral cases to rule out tibial apophyseal fracture, tumor, or infection (Fig. 1.2). Plain radiographs of SLJ can show slight separation and elongation, fragmentation, and/or irregular calcification of the distal patella ossification centers [22, 25]. Medlar et al described staging of the SLJ on radiograph with the following findings: Stage 1 normal findings, Stage 2 irregular calcifications at the inferior pole of the patella, Stage 3 coalescence of calcification, Stage 4A incorporation of the calcification into the patella, and Stage 4B a calcification mass separate from the patella [25].

An important differential diagnosis to be aware of are patellar sleeve fractures (discussed later in this chapter) as they look very similar to SLJ on radiographs. The distinction is the clinical presentation. Patellar sleeve fractures typically present after acute trauma, and the patient has severe pain with knee motion. They are also unable to extend the knee. If there is any doubt as to which condition the patient has, an MRI should be obtained. The distinction between these two conditions is important as treatment for sleeve fractures involves immobilization while treatment for SLJ does not.

SLJ is a self-limiting syndrome that typically resolves on its own within 12–18 months of presentation with the typical duration coinciding with heightened growth. Following presentation, patients are recommended to follow conservative

treatment plans with activity modification, application of ice, and use of nonsteroidal anti-inflammatory drugs NSAIDS for acute pain and swelling [26]. Once initial pain has subsided, a rehabilitation program focused on increasing strength and flexibility of quadriceps, iliotibial band, gastrocnemius, and hamstring muscles is recommended. We believe an important risk factor for SLJ is tight hamstrings, so increasing the flexibility of these muscles is particularly important. If pain does not abate, patients may benefit from rest and physical therapy followed by a slow return to sports with a supportive patellar sleeve [10].

Surgical treatments are very uncommon with SLJ, but they may be necessary in patients whose pain does not subside and continues into adulthood. Only one case report documenting successful surgical treatment of SLJ was found in the literature [27].

Bipartite Patella

Bipartite or tripartite patella is a congenital anomaly that is typically asymptomatic but can present with painful symptoms in the superolateral or lateral portion of the patella after overuse during activities or after trauma [28–30]. Of particular interest, bipartite patella is one of the only sources of superolateral knee pain and tenderness at presentation. The patella is the largest sesamoid bone in the body and typically develops with one center of ossification; bipartite patella occurs when one ossification center does not fuse with the main patella. Incidence is reported to be as low as 0.2–6% and as high as 60% [31–33]. Bipartite patella is more common in males than females with male to female ratios reported anywhere from 4:1 to 9:1 [33–35]. Symptomatic knees present more frequently in athletic, active adolescents than in inactive ones. Iossifidis et al. proposed that the etiology of painful bipartite patella was the disruption of the fibrocartilaginous zone between the patella and the accessory bipartite fragment due to direct or indirect injury [30].

History, clinical examination, and squatting skyline radiographs are used to diagnose bipartite patella. Ishikawa et al. described the squatting skyline view as most effective for viewing the bipartite patella and ruling out other causes of patellofemoral pain including hypoplasia, patellar instability, or abnormal patellar tracking [36]. On radiographs, bipartite patella appears in two parts with smooth, well-corticated borders (Fig. 1.3). Saupe developed a classification system for the location of the secondary ossification center. Type III is the most common at 75% incidence and appears in the superolateral region. Type II occurs in 20% of cases in the lateral or vertical region, and Type I in the inferior pole is least common at 5% [37]. MRI is also recommended for surgical patients. In addition, Kavanagh et al. indicated that MRI is particularly useful in young males with gradual onset of pain due to overuse and secondary abnormal patellofemoral tracking [38]. In these cases, MRI is not required to make the diagnosis of bipartite patella but may be useful to show the degree of edema at the synchondrosis of the bipartite patella and to evaluate the quality of the articular cartilage. All radiographs should be correlated with clinical

Fig. 1.3 Classic case of bipartite patella in a 13-year-old female

findings of tenderness and/or bony prominence over the lateral or superolateral portion of the patella. Symptoms typically worsen during knee extension when walking, jumping, and climbing stairs and during knee flexion.

This condition is typically self-limiting and most do not require surgery. Initial conservative treatments including NSAIDs, activity modification, local corticosteroid injections, and rehabilitation to increase quadriceps flexibility are recommended [33, 35]. In a meta-analysis of surgical treatment of bipartite patella, Matic et al. reported treatment of 130 knees in 125 patients with 90 out of 96 knees failing initial conservative treatment [34]. Surgical techniques including excision of the accessory fragment, lateral retinacular release [39], or vastus lateralis release [40] are indicated after conservative treatment fails at 6 months. For larger lesions in which excision would destabilize the patellofemoral joint, open reduction and internal fixation are recommended [28, 35]. Vaishya et al. report positive results in a case study of five patients undergoing excision or open reduction and internal fixation. All patients were pain- and symptom-free at average follow-up of 13 months [41]. Matic's meta-analysis also reports positive results with 105 of the 125 patients who underwent either surgical or conservative treatments being symptom-free and able to return to sports after intervention.

Trochlear and Patellar Juvenile Osteochondritis Dissecans (JOCD) of the Knee

Juvenile osteochondritis dissecans (JOCD) is an idiopathic condition characterized by the development of lesions in the subchondral bone of skeletally immature patients. This condition may or may not involve the overlying articular cartilage. JOCD is a fairly common cause of knee pain in athletic children and young adolescents with a reported rate of 15 to 29 cases per 100,000 [42, 43]. There is not yet a consensus on the etiology of OCD; however, several authors have proposed that OCD of the knee is an overuse injury from repetitive microtrauma to an area of vulnerable subchondral bone [44]. Once injured, loading and stress on this area can

result in avascular necrosis and potential non-union [44, 45]. This makes athletic children are more vulnerable to OCD; however, many cases of OCD occur in non-active children and recent genetic studies showing potential links between several DNA loci and OCD suggest a familial etiology [46]. The most common area in which OCD develops is the lateral aspect of the medial femoral condyle (50–80%) with trochlear and patellar lesions occurring at much lower incidence rates of 1% and 5–10%, respectively [44, 45, 47].

Patients typically present with knee pain and tenderness in the anterior medial part of the knee and swelling related to activity. They may walk with an antalgic gait or with the leg externally rotated. In terms of radiography, merchant and AP and lateral radiographs are the most helpful in diagnosing trochlear OCD [48, 49]. Once OCD is suspected, an MRI of the knee should be taken to confirm the diagnosis and track post-treatment progress (Fig. 1.4a–d).

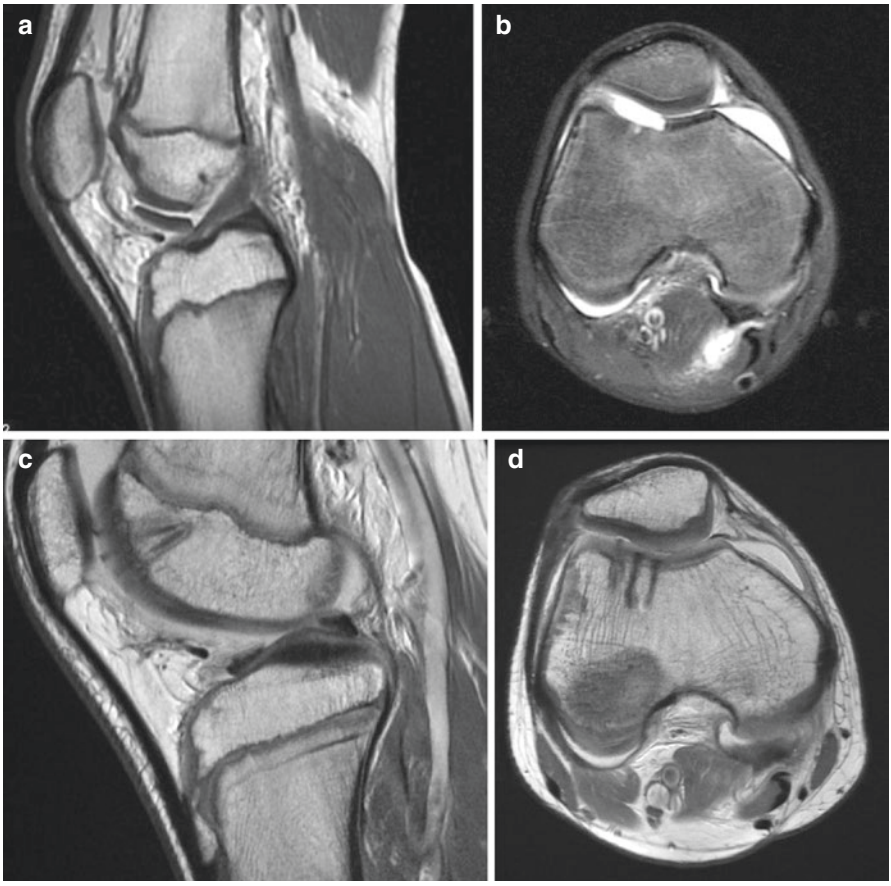

Fig. 1.4 (**a–d**) A 12-year-old male presented with OCD of the right trochlea. Patient underwent surgical fixation using eight bioabsorbable tacks. At 8 months follow-up, patient denies pain or symptoms and shows radiographic healing and incorporation. (Fig. 1.6a, b pre-op; Fig. 1.6c, d post-op)

Most studies on treatment for OCD have reported on femoral condyle lesions, and the American Academy of Orthopedic Surgeons (AAOS) clinical practice guidelines for treatment of OCD do not address trochlear lesions [50]. Due to the paucity of studies on its etiology and treatment, standardized treatments for trochlear OCD have not yet been established [51–54]. Due to the unique forces exerted on the patellofemoral joint, the diagnosis and treatment of trochlear OCD may differ from that of the femoral condyle. However, in the absence of conclusive studies, similar treatment guidelines as those for OCD of the femoral condyle are typically followed. Stable OCD lesions in skeletally immature patients respond well to non-operative treatment such as immobilization, non-weightbearing, or activity modification [55]. Operative intervention is indicated for patients with mechanical symptoms and evidence of loose body or unstable articular surface or those with closed growth plates. The goals of surgery are to reestablish the subchondral interface and preserve the overlying articular cartilage, ensure early motion, ideally preserve the bone without use of allograft, and achieve rigid fixation. Procedures include arthroscopy, chondroplasty, drilling, removal of loose bodies, lateral retinacular release, fixation, and allograft implantation. Postoperative management includes lateral retinacular stretching, patellar taping, and vastus medialis obliquus muscle exercises [56].

There is a paucity of literature reporting on the outcomes of surgical treatment for trochlear JOCD. Aside from several case reports, Wall et al. conducted a multicenter study of 24 cases of trochlear OCD treated either operatively (50%) or non-operatively ([51–53]). Of the operative patients, eight had surgical signs of healing and were able to return to sports. To better understand this rare condition, we conducted a retrospective cohort study of 30 patients with 34 trochlear JOCD lesions and report good short-term surgical outcomes. We also have found that there is an association with patients' participation in sports, specifically basketball and soccer that involve loading of the patellofemoral joint [57].

Similar to trochlear JOCD, the etiology and treatment for patellar JOCD are not well understood as it is also an uncommon location for lesions [44, 47, 58]. Patients typically present with anterior patellar pain similar to those with trochlear lesions. On imaging the lesion is typically seen on the posterior surface of the patella involving the overlying cartilage (Fig. 1.5a, b). Kramer et al. conducted one of the only studies evaluating treatment of both trochlear and patellar JOCD lesions. This surgical case series included 17 trochlear JOCD cases and 12 patellar JOCD and reported good clinical outcomes with 48% pain-free and 48% left with mild residual pain. At last follow-up, 85% of patients were able to return to sports, and the satisfaction scores and pedi-IKDC scores were positive [56]. In contrast to this study, some literature has reported less successful surgical outcomes for patellar OCD.

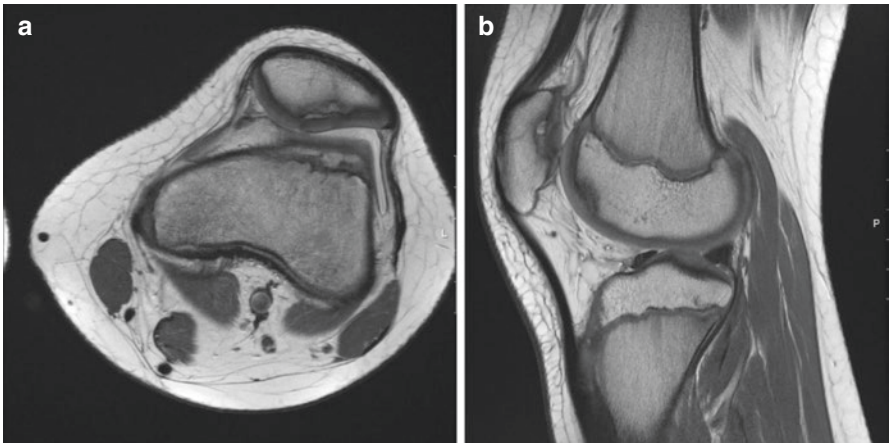

Fig. 1.5 (**a**, **b**) Preoperative images from a 12-year-old male presenting with unstable patellar OCD lesion of the left knee and a stable OCD lesion of the trochlea. Patient complains of anterior knee pain

Hoffa's Fat Pad Impingement

The knee joint is composed of three main fat pads: the anterior or infrapatellar fat pad (IFP), the intracapsular or quadriceps fat pad, and the extrasynovial or prefemoral fat pad. The infrapatellar fat pad (IFP) or Hoffa's fat pad is an intracapsular but extrasynovial wedge-shaped mass in the anterior region of the knee. The IFP extends from the inferior pole of the patella to the upper tibia and infrapatellar bursa and is delimited anteriorly by the patellar tendon and joint capsule and posteriorly by synovial membrane [59]. This structure acts as a shock absorber and guide for the patellar tendon. Hoffa's disease was first described by Albert Hoffa in 1904 as a cause of anterior knee pain resulting from impingement and inflammation of the IFP [60]. This impingement can be caused by multiple factors including patellar tendinitis, direct trauma such as sleeve fractures, or IFP tumors [61]. While tumors (typically benign) have been shown to be a source of pain in adult populations, they are far less common in children; however, it is important to be aware of tumors as a differential diagnosis [61]. In the absence of these underlying factors, fat pad impingement can often result after a hyperextension injury in which the fat pad is pinched. This injury can be caused by an acute closed degloving called the Morel-Lavallee lesion or by chronic exposure to repetitive shear forces and overuse [62]. Both of these types of injuries are most commonly seen in athletes such as dancers, gymnasts, or swimmers, whose activities require full knee extension. In response to impingement, the IFP becomes inflamed and swollen. If Hoffa's fat pad impingement is not addressed, it can result in fibrotic changes in cartilaginous or bony tissue including ossification of the fat pad [62].

Upon physical exam and patellar tendon palpation, patients present with tenderness along either side of the patellar tendon. This pain typically intensifies during flexion and extension [26]. In terms of radiography, plain radiographs are typically normal unless the condition has progressed into a chronic stage in which ossification is present. MRI is more helpful in diagnosing painfully impinged IFP as these cases often exhibit edema on MRI. Increased signal intensity on T2-weighted MRI of Hoffa's fat pad between the patellar ligament and lateral femoral condyle has been described as diagnostic of an impinged Hoffa's fat pad [63–65]. However several studies have shown that while edema in the superolateral region of Hoffa's fat pad is associated with clinical fat pad impingement, edema can also appear in patients without clinical pain [66, 67].

Several studies have also looked at the association of patellofemoral malalignment with Hoffa's fat pad impingement. Campagnes et al. report two types of patellofemoral malalignment that may be associated with impingement: a high-riding patella and an increased TT-TG distance, which may be associated with impingement [68, 69]. Campagna hypothesized that a high-riding patella could allow the patellar ligament to lie in front of the lateral trochlear facet and result in pressure between the patellar ligament and bone during motion [70]. Chung et al. also proposed that abnormal narrowing between the patellar ligament and bone could be associated with Hoffa's fat pad impingement [71]. Campagna et al. supported this study by observing an increase in patellar tendinopathy and decrease in the distance from the patellar tendon to bone in patients with edema due to impingement [70].

Initial treatment of impingement of Hoffa's fat pad typically involves physical therapy paired with NSAIDs to combat inflammation. If the impingement resulted from hyperextension, exercises targeting hamstring strength typically reduce the risk of repeated impingement. Injections of corticosteroids have been used in some clinics in an attempt to relieve pain in more extreme cases [72]. For patients who do not experience relief of symptoms with conservative treatment, surgical excision of the fat pad can provide relief [60, 72–74]. In addition, if a secondary morbidity such as an ossifying chondroma presents, a surgical arthroscopic resection is recommended [75].

Plica Syndrome

Plica syndrome or inflammation and thickening of the synovial folds around the patella typically occur in the medial superior portion of the medial retinaculum radiating toward the medial quadriceps tendon. "Synovial plicae" refer to four defined intracapsular folds in the synovial lining of the knee. These folds are remnants of septum-like divisions in the knee present during embryonic development [76, 77]. If these embryonic remnants fail to be reabsorbed as part of normal development, they become plica folds in adulthood [78]. These plicae are typically asymptomatic; however, blunt trauma, twisting injuries, or repetitive mechanical irritation from flexion extension activities can result in inflammation. Inflammation