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NON-OPERATIVE MANAGEMENT OF ANTERIOR KNEE PAIN (M FREDERICSON AND T BESIER, SECTION EDITORS)

Treatment Options for Patellofemoral Arthritis

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Abstract

Purpose of Review To present a synthesis of recent literature regarding the treatment of patellofemoral arthritis

Recent Findings Risk factors of PFJ OA include patella malalignment or maltracking, injury to supportive structures including the MPFL, dysfunction of hamstring and quadriceps coordination, lower limb alignment, trochlear dysplasia, patellar trauma, or ACL surgery. Special physical exam maneuvers include patellar grind test, apprehension test, and lateral patellar tilt angle. Radiographs that should be obtained first-line include weight bearing bilateral AP, lateral, and Merchant views. CT and MRI are used to assess trochlear dysplasia, excessive patellar height, and TT-TG distance. Non-operative management options discussed include non-pharmacologic treatment (patient education, self-management, physical therapy, weight loss), ESWT, cold therapy, taping, bracing, and orthotics. Pharmacologic management options discussed include NSAIDs, acetaminophen, oral narcotics, and duloxetine. Injection therapies include glucocorticoids, hyaluronic acid, PRP, and other regenerative therapies (BMAC, adipose, or mesenchymal stem cells). Other treatment options include radiofrequency ablation and botulinum toxin. The algorithm for the surgical treatment of PFJ OA can begin with arthroscopic assessment of the PF articular cartilage to address mechanical symptoms and to evaluate/treat lateral soft tissue with or without overhanging lateral osteophytes. If patients fail to have symptomatic improvement, a TTO can be considered in those patients less than 50 years of age or active patients >50 years old. In patients with severe PFJ OA, refractory to the above treatments, PFA should be considered. While early PFA design and technique were less than encouraging, more recent implant design and surgical technique have demonstrated robust results in the literature.

Summary Patellofemoral osteoarthritis is a challenging orthopedic problem to treat, in that it can often affect younger patients, with otherwise well-functioning knees. It is a unique entity compared to TF OA with distinct epidemiology, biomechanics and risk factors and treatment options.

Keywords Patellofemoral arthritis · Arthritis · Osteoarthritis

Introduction

Epidemiology

Patellofemoral osteoarthritis (PFJ OA) describes cartilage degeneration isolated to structures within the PF joint (PFJ), specifically the trochlear groove and underside of the patella. It can be developed primarily or post-traumatically. Post-traumatic patients typically have sustained a dislocation event in childhood followed by quiescent period and subsequent presentation with symptoms in mid-age. Patients with primary patellofemoral arthritis usually present at an older age due to chronic, non-traumatic degeneration due to malalignment or laxity.

This article is part of the Topical Collection on Non-Operative Management of Anterior Knee Pain

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PF OA is a distinct entity from medial and lateral compartment tibiofemoral joint (TFJ) arthritis but can occur concurrently. Duncan found that the most common radiographic pattern was TFJ and PFJ disease (40%), followed by PFJ OA only (24%), and TFJ OA only (4%) [1]. Davis and McAlindon found that the prevalence of isolated patellofemoral arthritis was 8–9%[2, 3] and that there was a higher prevalence in females (24%) compared to males (11%) [3].

The PFJ compartment is a key generator of symptoms associated with knee osteoarthritis (OA). The PFJ compartment compared to the TFJ compartment has been reported to have a higher frequency of radiographic osteophytes (218/334 vs 184/334) [4]. Kornaat and other groups found that osteophytes in the PFJ compartment were significantly associated with knee pain (OR 2.25), compared to those in the TFJ compartment (OR 1.19) [5–9].

Biomechanics

In a healthy patellofemoral joint, the articular cartilage can reach a thickness of up to 8 mm, which is the thickest cartilage in the human body [10]. The PFJ reaction force is increased by knee flexion [11]. The PFJ reaction force can reach over 3 times body weight with stairs and 7–8 times body weight during squats [12]. Therefore, patients are usually more comfortable ambulating on level ground and have increased pain with activities such as stair ascent or descent, lunges, and squats. PFJ malalignment also leads to increased reaction force due to decreased PFJ contact area, which ultimately places more stress on the area in contact.

Risk Factors for Primary Patellofemoral Osteoarthritis (Table 1)

Patella Malalignment/Displacement

Patella alignment relies on passive (bony and soft tissue) and active (muscle) structures. Patella malalignment presents with lateral patellar tilt or displacement. Niu found that knees with a laterally positioned patella and increased patella tilt laterally demonstrated a higher prevalence of PFJ OA [13]. Niu also found that patella subluxation is associated with knee pain severity and OA development [14]. In patients with isolated PFJ OA, Iwano found significantly greater lateral tilt of the patella compared with those who with both PFJ and TFJ OA [15].

Osseous

Shallow femoral trochlea groove depth (known as trochlear dysplasia) and patella alta are the two bony abnormalities that negatively impact patellar motion.

A randomized control demonstrated that knees with trochlear dysplasia showed higher patellofemoral degeneration and lower patellar cartilage volume than controls [16].

Patella alta occurs when the patella articulates with the femur more superiorly than normal. This position causes increased lateral patellar excursion that leads to increased shear forces and stress on the PFJ [17] and increased risk of patella instability and dislocation [18]. In a study by Stefanik, patients with elevated Insall-Salvati ratios (ISR) had increased odds of PFJ cartilage damage, bone marrow lesions, and subchondral bone attrition [19].

Ligaments

The medial patellofemoral ligament (MPFL) is the primary ligamentous stabilizer of the patella. The MPFL originates from the adductor tubercle and inserts onto the superomedial border of the patella. It provides resistance against lateral movement of the patella. Laxity or injury to the MPFL (typically in association with dislocation) contributed to patella instability and subsequent PFJ OA [20].

Secondary stabilizers include the lateral patellofemoral ligament and medial and lateral patellotibial ligaments and retinaculum.

Muscles

The quadriceps muscles provide dynamic stability for the patella. The vastus medialis obliquus (VMO) provides resistance against lateral translation. The vastus lateralis (VL) provides resistance against medial translation. Discrepancies in VMO and VL activity result in patella maltracking and increased PFJ pressures [21, 22]. Patients with patellofemoral syndrome have demonstrated a delayed onset of VMO activity relative to the VL during movement [23–27].

In addition to VL and VMO, core stability and lower extremity (LE) strengthening are integral components for LE biomechanics [28]. This is due to altered trunk and hip kinematics causing compensatory, altered knee kinematics [29•]. Strengthening hip muscles and improving lumbopelvic-hip core stability reduces reliance on the quadriceps muscle [30].

However, there is currently limited evidence for the impact of specifical physical therapy programs for PFJ OA [31]. An exercise program proposed by Crossley [32] included open- and closed-kinetic chain quadriceps strengthening, side lying hip abductor strengthening, functional retraining of the VMO and VL, hip abductor muscles, sit-to-stand, stepping up, and single-leg-squats. Quilty et al. [33] reported that a program of quadriceps strengthening exercise and medial patellar taping produced short-term improvement in knee pain and quadriceps strength compared to a control group that received no physiotherapy. Both studies did not maintain significant differences from controls after 6–12 months.

Table 1 Risk factors

Primary	*Post-traumatic*
Patella malalignment displacement	Trauma (patellar fracture, dislocation, subluxation)
Osseous	Prior surgery (ACL reconstruction)
Ligamentous	
Muscles	
Lowe limb malalignment	
Congenital	

Despite the lack of evidence for PFJ OA, there is more evidence for patellofemoral pain (PFP) physical therapy programs [31]. In both conditions, lower extremity muscle weakness is present, specifically the quadriceps, hip extensors, hip abductors, and hip external rotators. Alba-Martin [34] and Thomson [35] reported that programs incorporating hip abductor, hip external rotator, and quadriceps strengthening resulted in earlier PFP relief and improved function compared to quadriceps strengthening alone. This was corroborated by a systematic review and meta-analysis [36]. Yilmaz published a study demonstrating that women with PFP treated with core stabilization and knee exercises had decreased pain in improved function compared to controls who received only knee-focused exercises [37].

Lower Limb Malalignment

Lower limb alignment has been hypothesized to impact patellar tracking by changing the position of the femoral trochlea and altering soft tissue tension.

The Q-angle is a representation of the quadriceps force on the patella [38–40]. It is measured by the angle of one line through the center of the patella to the anterior superior iliac spine (ASIS) and a second line from the tibial tubercle through the center of the patella [41]. Normal values are between 13 and 18 degrees. Men have lower Q-angles than women. The Q-angle is the clinical correlate of the radiographic tibial tuberosity to trochlear groove distance (TT-TG).

An elevated Q-angle shifts the patella laterally, increasing pressure on the lateral patellar facet [38, 39, 42]. This may lead to increased risk of patellar subluxation or dislocation and PFJ OA. Causes of elevated Q-angles include valgus knee alignment, lateralized tibial tubercle, medialized center of trochlear groove, femoral anteversion, or excess tibial torsion. Cahue found that valgus knee alignment was associated with a 1.6 increase in the odds of isolated PFJ OA progression over 18 months [43].

Congenital

Trochlear dysplasia has been observed in 78% of patients with isolated PFJ OA [44]. In cadavers, implants with trochlear dysplasia had increased internal rotation, lateral tilt, lateral translation, increased contact pressures, decreased contact areas, and decreased stability compared to controls [45]. Patients undergoing patellofemoral arthroplasty had a higher rate of trochlear dysplasia compared to controls (55% versus 6%) [46].

Trochlear dysplasia is categorized by the Dejour classification, which is assessed by lateral knee radiographs and axial CT or MRI [47]. The classification is based on the presence of the crossing sign, a supratrochlear spur, and double contour sign [48]. The crossing sign is the deepest point on the trochlear sulcus that crosses the anterior border of the femoral condyles [49]. A supratrochlear spur is a prominence of the trochlea above the anterior femoral cortex. It is measured by the distance between a line tangential to the anterior femoral cortex and a line parallel to it through the trochlear groove. A double contour sign is present when the medial facet is hypoplastic and is visualized posterior to the lateral facet.

The Dejour classification:

Type A: crossing sign (flat or convex trochlea)
Type B: crossing sign and supratrochlear spur
Type C: crossing sign and double contour
Type D: crossing sign, supratrochlear spur, double contour, and sharp step-off of the trochlea.

Risk Factors for Post-Traumatic Patellofemoral Osteoarthritis

Trauma

Prior patella fractures and dislocations are risk factors for PFJ OA. Patella fractures have been reported to cause a 19.6% increased risk of PFJ OA development [50]. These fractures have also been associated with an increased risk of knee arthroplasty and arthroscopy (hazard ratio 1.83) [51]. Twenty-eight percent of patients with isolated PFJ OA have had a prior patella dislocation or subluxation [15]. In a study of 609 patients, about 50% had symptoms and radiographic changes of PFJ OA 25 years after patellar dislocation [52].

Prior Surgery

Anterior cruciate ligament (ACL) reconstruction is another risk factor for developing patellofemoral arthritis independent of hamstring tendon or bone-patellar-bone autograft. It is suspected to be related to altered biomechanics and pre-existing chondral damage [53•].

Clinical

History

Patellofemoral arthritis most commonly presents as chronic anterior knee pain aggravated by knee flexion [54]. Patients may also report popping, cracking, and grinding symptoms due to the friction of the patella in the trochlear groove. Providers should also assess risk factors such as prior patellar fractures, subluxation or dislocation events, which may cause symptoms of instability. Patients typically experience the worst pain in earlier stages of PFJ OA [54].

Physical

Inspection and Palpation

Palpation of the PFJ may demonstrate pain, crepitus, and effusion. Leslie reported that quadriceps wasting, effusion, and retropatellar crepitus are the most important physical exam findings indicative of PFJ OA [55]. Tenderness over the medial or lateral patellar facet is a sensitive but not specific indication of PFJ OA [56].

Range of Motion

PFJ OA patients may have decreased range of motion (ROM) in regard to flexion due to pain. During ROM, a J-sign can demonstrate patellar maltracking. The J-sign refers to the inverted "J" track the patella follows from extension to early flexion, which indicates potential instability [57]. The J-sign often correlates to severity of trochlear dysplasia and/or patella alta.

Strength

Quadriceps strength should be tested as these muscles are key stabilizers for the patella.

Special Tests

Patella-specific tests include the patellar grind test and patellar apprehension test.

The patellar grind test (Clarke test) is performed with the patient supine with full knee extension. The provider provides resistance with their hand on the proximal patella while the patient contracts their quadriceps muscle. A positive test is reproduction of their pain. The examiner may also passively move the patella while applying a posterior-directed force.

The patellar apprehension test involves applying a lateral-directed force over the patella when the knee is in full extension and 90 degrees of extension. A positive test is reproduction of pain or quadriceps contraction to minimize pain. This test demonstrates patellar laxity, which is a risk factor for developing PFJ OA. However, it is rare for the patient with PFJ OA to have continued symptomatic laxity or instability. Patients with PFJ OA decreased patella mobility.

The lateral patellar tilt (LPT) angle is used to assess patellar instability [58]. LPT is measured by the angle formed between the parallel line to the posterior aspect of both condyles and the diagonal line of the maximum width of the patella on axial MRI [59]. Increased LPT is associated with increased PFJ load [60–62].

Standing and Gait Alignment

Standing alignment and gait should be evaluated to identify squinting patella, foot pronation, valgus, or varus knees, and rotational malalignment of the tibia or femur. Gait findings associated with PFJ OA include increased anterior pelvic tilt, hip adduction, and decreased hip extension and increased contralateral lateral pelvic tilt [20]. The Q-angle may also be measured.

Diagnosis

Radiographs

Routine radiographic images include weight bearing bilateral AP, lateral, and axial views. These views can evaluate for joint space narrowing, subchondral sclerosis, osteophytes, articular degeneration, and patellar alignment. The lateral view can evaluate the height of the patella (Caton-Deschamps index), femoral condylar dysplasia, and arthritis.

Patella alta is measured on the lateral radiograph or sagittal MRI by the Caton-Deschamps index (CDI). CDI is the ratio of the distance between the anterior angle of the tibial plateau to the inferior aspect of the patellar articular surface compared to the patellar articular surface length. CDI is preferred due to its reliance on consistently identifiable and reproducible anatomical landmarks and is possible to measure regardless of the imaging quality, position of tibial tubercle, patellar modification, and knee flexion between 10 and 80 degrees [63].

The axial view (Merchant or sunrise view) can evaluate for patellar malalignment, trochlear groove depth, and joint space narrowing. The lateral and axial views can specifically evaluate the PFJ space.

PFJ OA is classified into four stages based on the Merchant view [20]:

1. Mild — more than 3 mm of joint space
2. Moderate — less than 3 mm of joint space but not bony contact
3. Severe — bony surfaces in contact over less than one-quarter of the joint surface
4. Very severe — bony contact throughout the entire joint surface

Another measurement on the Merchant view is the congruence angle. It is used to measure lateral patellar displacement and is around −6 degrees [64].

CT and MRI

Computed tomography (CT) and MRI can help identify three major anatomic factors of instability from the Lyon School: trochlear dysplasia, patella alta, and pathological TT-TG distance [65]. The Dejour classification is specifically based on CT scans.

Treatment

Since most studies have grouped together PFJ and TFJ OA, there is little evidence guiding the conservative management of PFJ OA specifically. However, we will review the current evidence for general knee OA.

Non-pharmacologic Treatment (Table 2)

Patient Education

Providing patient education is a core recommendation from the 2019 OARSI and 2021 AAOS guidelines. Patients' beliefs about pain shape their attitudes and behaviors on how to manage their symptoms. A Cochrane review examined twenty-one trials (2372 participants) [66] that demonstrated that patients without education from healthcare professionals tended to avoid activity for fear of causing harm. Recommended patient education topics include disease etiology, prognosis and management options and clearance for participation in exercise programs tailored to patient fitness level and preferences.

Patient Self-Management

Patient self-management is strongly recommended by the 2019 OARSI and 2021 AAOS guidelines. However, the specific forms of self-management remain unclear.

A systematic review of seven studies evaluated the effectiveness of group-based and face-to-face self-management education programs for patients with knee OA [67]. Due to heterogeneity among sample population, type of intervention, and comparison arms, the efficacy of these programs remained inconclusive.

A Cochrane Review analyzed twenty-nine studies with 6,753 participants that compared self-management education programs to attention control, usual care, information alone or another intervention [68]. Compared to usual care, there was low to moderate quality evidence which indicates that self-management education programs may slightly improve self-management skills, pain, function, and symptoms. The benefits were deemed to be unlikely of clinical significance.

Exercise/Physical Therapy

Patients with knee OA benefit from multi-modal, therapeutic exercise [69, 70]. Strength training, aerobic exercise, and neuromuscular exercise are strongly recommended by the 2019 OARSI and 2021 AAOS guidelines. Exercise benefits improving aerobic fitness, ROM, and strength and decreasing fall risk. Studies showing benefit have involved aerobic exercise (e.g., treadmill, track, or walking), strengthening (isokinetic, isometric, or elastic-band exercises), neuromuscular exercise, aquatic activities, balance exercise, and mind–body exercise. In a systematic review and meta-analysis of 14 randomized controlled trials with 815 patients, traditional Chinese exercise programs such as Tai Chi significantly improved psychological health, pain, stiffness, and function at a follow-up of up to 24 weeks [71, 72].

Land Exercise

Regarding the benefit of land-based exercise, a Cochrane review examined data from 54 studies [73]. High-quality evidence indicates that land-based therapeutic exercise decreases pain and improves function in knee OA patients that was sustained for at least 2 to 6 months after cessation of formal treatment. The magnitude of the treatment effect was comparable to that provided from non-steroidal anti-inflammatory drugs (NSAIDs).

Aquatic Exercise

Aquatic environments allow low-impact aerobic, strengthening, and range-of-motion exercises but are less accessible than land-based options. Regarding the benefit of aquatic therapy, a Cochrane Review examined 13 studies with 1190 patients. The participants were predominantly female (75%), with a mean age of 68 years, 6.7-year duration of OA, and a mean body mass index (BMI) of 29.4 [74]. The average aquatic exercise program length was 12 weeks. These programs were found to have a small, short-term improvement in pain and disability compared to controls.

Table 2 Non-pharmacologic management options

Intervention	*ACR 2019*	*AAOS 2021*	*OARSI 2019*
Exercise	Strongly recommended	Strongly recommend	Strongly recommend
Balance training	Conditionally recommended	Moderately recommend	Strongly recommend
Weight loss	Strongly recommended	Moderately recommend for patients with symptomatic knee OA and BMI ≥25	Strongly recommend
Self-management	Strongly recommended	Strongly recommend	Conditionally recommend (high consensus)
Tai Chi	Strongly recommended		Strongly recommend
Yoga	Conditionally recommended		Strongly recommend
Cognitive behavioral therapy	Conditionally recommended		Conditionally recommend (low consensus)
Cane	Strongly recommended	Moderately recommend	Conditionally recommend (high consensus)
Tibiofemoral braces	Strongly recommended	Moderately recommend	
Patellofemoral braces	Conditionally recommended	Moderately recommend	
Kinestiotaping	Conditionally recommended	Inconclusive	
Modified shoes	Conditionally recommended against		
Lateral and medial wedged insoles	Conditionally recommended against	Moderately recommend against	
Acupuncture	Conditionally recommended	Limited evidence	
Thermal interventions	Conditionally recommended	Limited evidence	
Radiofrequency ablation	Conditionally recommended	Limited evidence	
Massage therapy	Conditionally recommended against	Limited evidence	
Manual therapy	Conditionally recommended against	Limited evidence	
Pulsed vibration therapy	Conditionally recommended against	Limited evidence	
Transcutaneous electrical nerve stimulation	Strongly recommended against	Limited evidence	
Extracorporeal Shockwave therapy		Limited evidence	

Stationary Cycling

In a systematic review of eleven studies with 724 participants, stationary cycling was found to improve pain and function but did not provide significant improvement in quality of life and stiffness [75]. Using a higher-level seat and lower resistance can avoid bringing on PFP symptoms.

Weight Loss

AAOS guidelines moderately recommend weight loss in patients with symptomatic knee and a BMI ≥25. The lifetime risk of developing knee OA symptoms is 60% in obese patients [76]. A meta-analysis examined 30 with 4651 patients (74.6% women). The most effective interventions for pain reduction were bariatric surgery, low-calorie diet and exercise, and intensive weight loss and exercise. For every 1% weight loss, Western Ontario and McMaster Universities Osteoarthritis (WOMAC) pain, function, and stiffness scores decreased by about 2%.

Extracorporeal Shockwave Therapy

Extracorporeal shock waves (ESWT) [77] generate acoustic high-pressure waves [78–80], which causes interstitial and extracellular responses leading to tissue regeneration [81]. Specifically, ESWT first causes compression during the positive phase and then tensile force and shear stress in the negative phase, which leads to microbubbles that exert cavitational effects on the area of the treatment. ESWT enhances subchondral bone anabolism and improves trabecular bone quality through modulation of inflammatory and growth factor signaling molecules [82–85]. Five recent meta-analyses demonstrated that ESWT improves function (WOMAC and visual analog scale scores) of patients with knee OA at a follow-up of up to 6 months [77, 86–89]. The energy flux density applied during ESWT is a critical component for treatment effectiveness. Per 2021 AAOS guidelines, evidence remains limited at this time [90•]. Further investigation is needed to determine ESWT parameters, dosage, and long-term effects.

Cold Therapy

Cold therapy can be administered by application of *ice* packs. Patients should be instructed to limit the use to 20-min intervals. A Cochrane review examined three randomized controlled trials, involving 179 patients [91]. Ice massage compared to controls had a statistically significant improvement on ROM, function, and strength but did not affect pain. Cold packs decreased swelling. Hot packs did not provide any beneficial effect.

Patellar Taping

Patella taping (McConnell taping) is applied to prevent lateralization of the patella. In a small cross-over study of 14 patients with PFJ OA, taping the patella in a medial direction for 4 days resulted in a 25% reduction in pain [92]. It is suspected that changes in patella position may decrease forces sustained by the PFJ. A recent review did not demonstrate a clinically significant improvement in pain or function with elastic taping for patients with primary knee OA [93].

Bracing and Orthotics

Similar to taping, patella stabilizing braces aim to shift the patella medially and decreased PFJ forces. In patients with PFP, patella stabilizing braces have been shown to reduce pain by increasing PFJ loading area [94, 95]. As PFJ OA is associated with valgus knee alignment, interventions that provide alignment correction such as proprioceptive sleeves, wedged orthotics or valgus offloading braces may possibly reduce symptoms. However, these types of braces have not been evaluated specifically in patients with PFJ OA.

A Cochrane Review examined 13 studies (n = 1356) [96] of participants' knee OA with a knee brace (valgus knee brace, neutral brace, or neoprene sleeve), an orthosis (laterally or medially wedged insole, neutral insole, variable or constant stiffness shoe), or no treatment.

Evidence was inconclusive for the benefits of bracing. There was moderate-quality evidence demonstrating a lack of effect on pain, stiffness, and function between patients treated with a laterally wedged insole and those treated with a neutral insole. There was low-quality evidence of a lack of an effect on pain, stiffness, and function between patients treated with a valgus knee brace and those treated with a laterally wedged insole. The American Academy of Orthopedic Surgeons (AAOS) strongly recommends against the use of lateral wedge insoles for patients' knee OA but moderately recommends for the use of canes and braces to improve pain and function [90•].

Insufficient Evidence

Treatments with insufficient evidence: dry needling [90•], therapeutic ultrasound [97], manual therapy [32], electromagnetic fields [98], transcutaneous electrical stimulation [99], acupuncture [100], ozone, blood flow restriction training [101, 102], high vs. low intensity exercise [103], percutaneous electrical nerve stimulation, pulsed electromagnetic field therapy, massage, and laser treatment [90•].

Table 3 Pharmacologic management options

Intervention	*ACR 2019*	*AAOS 2021*	*OARSI 2019*
Topical NSAIDs	Strongly recommended	Strongly recommended	Strongly recommend
Topical capsaicin	Conditionally recommended		
Oral NSAIDs	Strongly recommended	Strongly recommended	Conditionally recommend (high consensus)
Intra-articular glucocorticoid injection	Strongly recommended	Moderately recommend	Conditionally recommend (high consensus)
Acetaminophen	Conditionally recommended	Strongly recommended	
Duloxetine	Conditionally recommended		Conditionally recommend (low consensus)
Tramadol	Conditionally recommended	Strongly recommended against	
Non-tramadol opioids	Conditionally recommended against	Strongly recommended against	
Colchicine	Conditionally recommended against		
Fish oil	Conditionally recommended against	Limited evidence	
Vitamin D	Conditionally recommended	Limited evidence	
Bisphosphonates	Strongly recommended against		
Glucosamine	Strongly recommended against	Limited evidence	
Chondroitin sulfate	Strongly recommended against	Limited evidence	
Hydroxychloroquine	Strongly recommended against		
Methotrexate	Strongly recommended against		
Intra-articular hyaluronic acid injection	Conditionally recommended against	Moderately recommend against	Conditionally recommend (low consensus)
Intraarticular botulinum toxin Therapy	Conditionally recommended against		
Prolotherapy	Conditionally recommended against		
Platelet-rich plasma	Strongly recommended against	Limited Evidence	
Stem cell injection	Strongly recommended against	Limited Evidence	
Biologics (tumor necrosis factor inhibits, interleukin-1 receptor antagonists)	Strongly recommended against		

Pharmacologic (Table 3)

Non-steroidal Anti-Inflammatory Drugs (NSAIDs)

Per the Osteoarthritis Research Society International (OARSI) American College of Rheumatology (ACR) 2019 guidelines and 2021 AAOS guidelines, topical NSAIDs are the first-line treatment for knee OA due to their low risk of gastrointestinal, cardiovascular, and renal side effects [90•, 104, 105].

Among OA patients with moderate to severe levels of pain, NSAIDs can be more effective than acetaminophen. A Cochrane review examined 15 RCTs involving 5986 participants [106]. Current evidence demonstrates that NSAIDs are superior to acetaminophen for improving knee and hip OA. However, the treatment effect was modest and the median trial duration was 6 weeks.

There is no convincing evidence that any particular NSAID is more effective than other NSAIDs. A Cochrane Review examined the effect of celecoxib in 36 trials that provided data for 17,206 adults [107]. Current evidence indicates that celecoxib is slightly better than placebo and some NSAIDs in increasing pain and improving function. However, many of the studies were at risk of bias due to pharmaceutical industry involvement or were of low-quality evidence.

Oral NSAIDs should only be used intermittently for the shortest duration and at the lowest effective dose due to cardiovascular, hepatic, and renal side effects per OARSI, ACR, and AAOS guidelines. Oral NSAIDs in combination with a PPI or selective cyclooxygenase 2 inhibitor are recommended. In those with cardiovascular risk factors, both societies suggest limiting the use of COX2 inhibitors to 30 days and non-selective NSAIDs to 7 days. OARSI recommends the use of any oral NSAIDs.

Per the OARSI guidelines, NSAIDs are not recommended for use in patients with frailty. Increased age predisposes patients to cardiovascular, cerebrovascular, and gastrointestinal side effects [108, 109]. There is also evidence to suggest that age increases the relative risk of NSAID side effects. Therefore, oral NSAIDs are not recommended to be used in patients over 65 years [110].

Acetaminophen

The AAOS strongly recommends use of acetaminophen [90•]. Acetaminophen was previously the initial therapy for mild OA because it is inexpensive, relatively safe, and effective. A Cochrane review examined 10 randomized placebo-controlled trials involving 3541 participants with hip or knee OA [111]. There was high-quality evidence that acetaminophen provided minimal improvements in pain and function for people with hip or knee OA without increased risk of adverse events.

Oral Narcotics

Oral narcotics should not be routinely recommended in the non-operative treatment of PFJ OA. The AAOS strongly recommends that oral narcotics including tramadol are not effective for improving pain or function in knee OA and result in significant adverse events [90•]. Tramadol is a dual-acting weak μ-receptor inhibitor with serotonin reuptake inhibition that should be used with caution in older adults with OA and preferably only for limited duration in the lowest effective dose. In a Cochrane review of 22 RCTs [112], moderate-quality evidence indicates that tramadol has no significant benefit for pain or function in patients with OA. There was also moderate-quality evidence of increased adverse events.

For other oral narcotics, a Cochrane review analyzed 22 trials with 8275 participants [113]. Oral oxycodone was studied in 10 trials, transdermal buprenorphine and oral tapentadol in four, oral codeine in three, oral morphine and oral oxymorphone in two, and transdermal fentanyl and oral hydromorphone in one trial each. The small mean benefit of non-tramadol opioids is contrasted by significant increases in the risk of adverse events such as nausea, vomiting, lightheadedness, dizziness, or headache.

Duloxetine

For up to 13 weeks, duloxetine has been shown to provide statistically significant benefit for pain, function, and quality of life for patients with knee OA [114]. Another analysis included six randomized controlled trials with 2059 participants [115]. Duloxetine achieved significant reductions in primary outcomes including Brief Pain Inventory 24-h average pain score, weekly mean of the 24-h average pain score, WOMAC stiffness and physical function. However, incidence of gastrointestinal side effects was three to four times higher compared to placebo without a significant difference in serious adverse events.

Insufficient Evidence

The AAOS recommends that turmeric, ginger extract, glucosamine, chondroitin, and vitamin D may be helpful in improving pain and function for patients with mild to moderate knee OA. However, evidence remains limited for each supplement [90•].

Other options with insufficient evidence to support use include the following: *Boswellia serrata*, avocado-soyabean unsaponifiables (ASU) [116], Arnical gel, Comfrey extract, Capsicum extract [117], turmeric [118], S-Adenosylmethionine (SAMe) [119], doxycycline [120], biologics (inhibitors of IL-1 or tumor necrosis factor α).

Injections

There are no studies examining the effectiveness of any injections for the treatment of patellofemoral arthritis specifically.

Glucocorticoids

Corticosteroids are one of the widest used forms of intra-articular therapy. They have been in use since the 1950s [121]. There are three main formulations used: methylpredinisolone, triamcinolone, and betamethasone [122]. Corticosteroids block the inflammatory cascade by inhibiting compounds including phospholipase A2, its derivatives (leukotrienes, prostaglandins), and inflammatory cytokines (matrix metalloprotease, neutrophil superoxide) [123].

In a Cochrane review, 27 trials with 1767 participants were analyzed [124].

The clinically significant benefit remained unclear due to heterogeneity between trials, and evidence of small-study effects. There were no lasting effects demonstrated after 6 months after the injection.

The OARSI, ACR, and AAOS guidelines support the use of intra-articular corticosteroid injections for short-term relief [90•].

Despite these recommendations, there is concern that intra-articular injection of local anesthetic and/or corticosteroids may cause potential toxicity to chondrocytes and synoviocytes, after even a single exposure. Local anesthetics should be avoided in the joint. A saline vehicle should be used instead.

Of the corticosteroid classes, Kenalog has been demonstrated to be the least cytotoxic [125]. In a study by Nuelle, supraspinatus tendon explants were obtained from dogs and randomly assigned to one of the following groups: culture media only, 1% lidocaine, 0.5% lidocaine, 0.25% bupivacaine, 0.125% bupivacaine, 0.0625% bupivacaine, 5 mg betamethasone acetate, 40 mg methylprednisolone acetate, or 40 mg triamcinolone acetonide. In tenocytes exposed to 1% lidocaine, betamethasone, and methylprednisolone, there were significant decreases in cell viability and metabolism noted at days 1 and 7. Tenocytes exposed to 0.125% bupivacaine, 0.0625% bupivacaine, and triamcinolone demonstrated no decrease in cell viability or metabolism.

Sherman et al. [126] performed a study on full thickness canine chondral and synovial samples exposed to the following for 24 h: 1% lidocaine, 0.5% lidocaine, 0.25% bupivacaine, 0.125% bupivacaine, 0.0625% bupivacaine, betamethasone acetate, methylprednisolone acetate, triamcinolone acetonide, or culture media only (control). Complete loss of chondrocyte and synoviocyte viability was noted in the 1% and 0.5% lidocaine group, 0.25% and 0.125% bupivacaine group, betamethasone group, and methylprednisolone groups after 1 and 7 days of culture. Treatment with 0.0625% bupivacaine and triamcinolone demonstrated no decrease in cell viability or metabolism when compared to negative control.

In a study by Nuelle et al., [127] twenty adult dogs underwent ultrasound-guided injection of the canine equivalent of the subacromial space with one of four different treatments: normal saline, 1.0% lidocaine/methylprednisolone, 1.0% lidocaine/triamcinolone, or 0.0625% bupivacaine/triamcinolone. Tendons exposed to 1% lidocaine/methylprednisolone had significantly lower cell viability at day 1 as compared to all other groups and control. All local anesthetic/corticosteroid combination groups had decreased cell viability at day 7 when compared to the control group.

Hyaluronic Acid

Hyaluronic acid is a type of glycosaminoglycan synthesized by the synovium to act as a joint lubricant and shock absorber [128]. Intra-articular injections of hyaluronic acid (IAHA) have also been frequently used in the treatment of knee OA, but there remains uncertainty regarding its use. Hyaluronic acid injections have been shown to potentially improve pain and function in PFJ OA after 4–26 weeks [129]. However, severe PFJ OA is a predictor for IAHA failure [130].

In a Cochrane review of 76 trials for general knee OA, IAHA improved pain, function, and patient global assessment particularly between 5 and 13 weeks after injection [131].

OARSI guidelines recommend IAHA while AAOS and ACR have a moderate strength recommendation against its use [90•].

Platelet-Rich Plasma

Platelet-rich plasma (PRP) consists of platelet growth factors that are hypothesized to improve chondrogenesis, cell proliferation, angiogenesis, cell differentiation, and bone remodeling. In a systematic review and meta-analysis of 18 randomized controlled trials of 811 knee OA patients, PRP had improved clinical outcomes (VAS, WOMAC, IKDC) when compared with IAHA [132]. Leukocyte-poor PRP may be superior to leukocyte-rich PRP, but further studies are needed. Leukocyte-rich PRP may have a higher concentration of growth factors but with a concurrent increase proteases and reactive oxygen species released from white blood cells. Evidence remains limited per most recent AAOS guidelines [90•].

Other Regenerative Techniques

Bone marrow aspirate concentration (BMAC) and adipose are more invasive and more expensive with limited evidence specific for PFJ OA. All injections have less efficacy in moderate-

severe disease compared to mild disease. Further studies regarding their indications and effectiveness are needed.

Mesenchymal Stem Cells Mesenchymal stem cells (MSCs) can differentiate into different cell types and are hypothesized to regulate inflammation and improve growth actors. They can be derived from bone marrow, and placental and adipose tissue. A meta-analysis of 19 studies with 440 knees was performed. Intra-articular MSC injections were shown to improve pain and function for knee OA [133]. Another meta-analysis including 7 trials with 256 patients also demonstrated improved pain and function scores but no evidence of cartilage regeneration on knee MRI [134]. Both analyses concluded that significantly better outcomes were obtained with bone marrow–derived MSCs as compared with adipose- or umbilical-cord-derived MSCs. Further studies are needed to determine preparation and dosage.

Bone Marrow Aspirate Concentration [135] Bone marrow aspirate concentration (BMAC) is comprised of a mixture of MSCs and growth factors such as cytokines, chemokines, growth factors, marrow elements, and mesenchymal stem cells [136]. These components are involved in pathways related to cell maintenance and function, differentiation, and extracellular matrix production. BMAC is considered a minimally manipulated compound and authorized by the US Food and Drug Administration (FDA) [137].

A systematic review by Cavallo identified 11 studies related to BMAC and knee OA. BMAC demonstrated an overall improvement in pain and function but did not demonstrate superiority over the other intra-articular options, and its effects did not outperform saline controls after 12 months of follow-up [138]. When combined with platelet products, BMAC injections demonstrated better results than exercise therapy in knee OA patients at 24 months of follow-up [139] and had similar results compared with total knee arthroplasty in younger patients with knee OA secondary to corticosteroid-related osteonecrosis at an average of 12 years of follow-up [140]. Further studies are needed to support routine clinical use.

Botulinum Toxin

There is increasing evidence that botulinum toxin type A (BoNT-A) can improve pain by reducing peripheral and central sensitization [141]. In a systematic review of 5 randomized control trials including 314 patients [142], there was a significant difference between BoNT-A and placebo in the VAS and WOMAC scores in both short-term (≤4 weeks) and long-term (≥8 weeks) follow-up. In another meta-analysis of 6 studies with 382 patients [143], BoNT-A intra-articular injections had a decreased in VAS scores by 1 point until 6 months. Further studies are needed to support routine clinical use.

Radiofrequency Ablation

Genicular nerve radiofrequency ablation (RFA) is an option for chronic pain due to knee OA. It works by ablating sensory nerves supplying painful tissue thereby blocking the transmission of pain signals. In a meta-analysis of 9 randomized controlled trials, RFA was associated with improvements in pain, Lequesne Index, and WOMAC scores at up to 24-week follow-up [144]. Evidence remains limited per most recent AAOS guidelines [90•].

Surgical Management

Surgical management of PFJ OA has greatly evolved over the past decade and now includes a spectrum of treatment options including patellofemoral arthroplasty. Early PFJ OA with mechanical symptoms or significant activity limitation is often first addressed by surgical debridement, removal of loose bodies, and chondroplasty to help improve the longevity of the native patellofemoral joint and function. Arthroscopic or open lateral lengthening can be a very useful tool to address PFJ OA, especially in the context lateral trochlear or lateral patella osteophytes. By performing a lateral lengthening, the articular surface of the lateral patella is offloaded as it tracks more centrally in the trochlear groove. Lateral lengthening procedure has had mixed outcomes; however, a recent study of 50 patients with PF pain who underwent lateral release reported significantly greater post-operative satisfaction compared with PF instability patients [145]. It must be highlighted that lateral retinacular lengthening is preferred to lateral release because it maintains lateral soft-tissue integrity while also providing symptomatic relief and avoids iatrogenic medial patella instability [146].

If insufficient improvement in patella gliding is observed with arthroscopic treatment as outlined, a tibial tubercle osteotomy (TTO) can be considered a next step in the treatment algorithm. TTO involves moving the tibial insertion of the patella tendon anterior and medially, which in effect, improving patellofemoral tracking and shifting forces proximal and medial. The result is a decrease in contact forces between the patella and trochlea. Patients best indicated for lateral lengthening procedures and/or TTO are patients younger than 50 years of age, with isolated mild to moderate lateral patellofemoral arthritis and malalignment (i.e., TT-TG>15mm). However, Carofino et al. [147] studied active patients greater than 50 years of age and demonstrated TTO to produce a post-operative Lysholm Score of 83. When patients develop widespread and severe PFJ OA, surgical treatment moves towards patellofemoral arthroplasty (PFA).

Osteochondral allograft transplant (OCA) offers a viable treatment for patients with early-stage PFA. However, the current contraindications to OCA must be highlighted. A recent Delphi study of expert patellofemoral surgeons aided in

Table 4 Indications and contraindications for PFA in the setting of primary, isolated PFOA

Indications	*Contraindications*
Isolated, advanced patellofemoral arthritis	Focal chondral lesion of patella or trochlea amenable to other treatment
Failed non-operative management with progressive pain and disability	Tibiofemoral OA
Failed lateral lengthening procedures and/or bony realignment procedures	Severe PF malalignment
Trochlear dysplasia	Valgus deformity >8 degrees, varus deformity > 5 degrees
Post-traumatic PFOA	

the development of these contraindications: [148] patients with bipolar trochlear/patella lesions or OA, end-stage OA, and patients with very restricted ROM should not be indicated for OA of the PF joint. OCA may be considered in patients with large osteochondral lesions on either the patella or trochlea, and in patients with early-stage arthritis, especially in those with cartilage loss in one region of either the patella or trochlea. Spak et al. [149] studied the 10- and 5-year survivorship of OCA for PFJ OA and demonstrated 57% survivorship for greater than 10 years with associated 46- and 30-point improvement in knee and functional scores, respectively. In a recent systematic review of OCA for large PF chondral lesions [150], pooled survivorship was found to be 87.9% at 5 years, 77.2% at 10 years, and 55.8% at 15 years. However, it must be highlighted that many of the included studies performed concomitant soft tissue balancing or alignment procedures at the time of OCA. In the correct patient population, OCA for PFJ OA can provide symptomatic relief with good survivorship and can delay the need for PFA or TKA.

Patellofemoral arthroplasty has emerged as a promising treatment for PFJ OA. Good indications of PFA include patients with isolated PFJ OA, with intact medial and lateral compartment articular surfaces. PFA also can also improve alignment by moving groove center centrally (effectively reducing TT-TG ratio), and allows the surgeon to place the PF button to adjust for patella alta and lateralized tracking. PFA offers a distinct advantage over total knee arthroplasty (TKA) in that patients maintain their tibiofemoral articulations and the cruciate ligaments, leading to more native knee kinematics. Early criticism of PFA was due to the high early failure rate of PFA. However, further research and innovation have been demonstrated that the observed failure rates were likely secondary to implant deign and surgeon technique [151]. Newer implant design and advancement of surgical techniques have allowed for improved patient-reported outcomes at midterm follow-up [152]. A recent randomized control trial comparing TKA and PFA demonstrated similar functional outcome scores between the two procedures when used for isolated PFJ OA at 12-month follow-up. Moreover, there was no significant difference in surgery-related complications between TKA and PFA [153].

Recent meta-analyses have corroborated these findings, demonstrating PFA to produce significant improvement in WOMAC score at 5-year follow-up, less post-operative inpatient time, better cost-effectiveness, and significantly less blood loss when compared to TKA [154].

Similarly, Peng et al. [155] performed a meta-analysis examining outcomes, complications, and revision rates of both PFA and TKA for isolated PFJ OA. A total of seven studies comprised of 3 RCT and 4 non-randomized controlled trials were included. The authors found that in the first 2 years postoperatively, patients who underwent PFA had significantly higher activity and better functional outcomes compared to TKA patients [155]. Taken together, recent both individual and pooled data suggest that PFA is a promising treatment modality for isolated PFJ OA, and can produce significant improvement with relatively low complication and revision rates (Table 4).

Conclusion

PFJ OA is a challenging orthopedic problem to treat, in that it can often affect younger patients, with otherwise well-functioning knees. It is a unique entity with distinct epidemiology, biomechanics, and risk factors compared to TF OA. Risk factors of PFJ OA include patella malalignment or maltracking, injury to supportive structures including the MPFL, dysfunction of hamstring and quadriceps coordination, lower limb alignment, trochlear dysplasia, patellar trauma, or ACL surgery. History and physical should evaluate for these risk factors. Special physical exam maneuvers include patellar grind test, apprehension test, and lateral patellar tilt angle. Radiographs that should be obtained first-line include weight bearing bilateral AP, lateral, and Merchant views. CT and MRI are used to assess trochlear dysplasia, excessive patellar height, and TT-TG distance.

Non-operative management options discussed include non-pharmacologic treatment (patient education, self-management, physical therapy, weight loss), ESWT, cold therapy, taping, bracing, and orthotics. Pharmacologic management options discussed include NSAIDs, acetaminophen, narcotic

analgesics, and duloxetine. Injection therapies include glucocorticoids, hyaluronic acid, PRP, and other regenerative therapies (BMAC, adipose, or mesenchymal stem cells). Other treatment options include radiofrequency ablation and botulinum toxin.

The algorithm for the surgical treatment of PFJ OA can begin with arthroscopic assessment of the PF articular cartilage to address mechanical symptoms and to evaluate/treat lateral soft tissue with or without overhanging lateral osteophytes. If patients fail to have symptomatic improvement, a TTO can be considered in those patients less than 50 years of age or active patients >50 years old. In patients with severe PFJ OA, refractory to the above treatments, PFA should be considered. While early PFA design and technique were less than encouraging, more recent implant design and surgical technique have demonstrated robust results in the literature.

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