Review Article

Chondral and osteochondral lesions in the patellofemoral joint: when and how to manage

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Abstract: Treatment of chondral and osteochondral lesions of the patellofemoral (PF) joint is complex as it typically must address the multifactorial etiology. A thorough history, physical exam, and imaging are essential to appropriately assign symptoms to the PF joint and cartilage pathology. This approach allows planning an appropriate course of treatment. Non-operative treatment is the primary course of action for most patients; however, upon exhausting all conservative options, persistently symptomatic patients may be candidates for surgical restoration. Lesion characteristics, patient, limb, and joint specific factors must all be considered to achieve optimal results. With careful pre-surgical planning, meticulous technique, and compliance with post-operative rehabilitation program, good to excellent outcomes may be achieved.

Keywords: Patellofemoral (PF); patella; trochlea; cartilage; restoration

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Introduction

Successful treatment of chondral and osteochondral injury in the patellofemoral (PF) joint remains a clinical challenge. The etiology of symptomatic chondral/osteochondral pathology is complex and often multifactorial. Diverse causes include, but are not limited to, traumatic impaction, PF instability events, repetitive microtrauma and/or chronic overload in the setting of malalignment and/or obesity, and osteochondritis dissecans (OCD) lesions. To select an appropriate non-operative or operative treatment strategy, the surgeon must have a comprehensive understanding of all patient specific, lesion specific, and joint/limb specific variables. If cartilage restoration is indicated, optimization of joint biomechanics through concomitant bony and/or soft tissue procedures will maximize the opportunity for a good outcome. This paper will focus on the evaluation and treatment of symptomatic chondral/osteochondral lesions in the PF joint. Our goal is to aid the surgeon in their decision making regarding when and how to manage these lesions.

Epidemiology

Chondral and osteochondral defects in the PF compartment are often encountered in clinical practice on advanced imaging studies and/or during arthroscopy. A review of a Polish registry found that more than half of patients undergoing knee arthroscopy had chondral defects, with 5.2% having Outerbridge Grade III or IV lesions. Of these, 37.5% were in the patella alone (1). Curl *et al.*, in a review of 31,516 knee arthroscopies, found over 53,000 hyaline cartilage lesions in over 19,000 patients; most of the lesions found were actually grade III defects in the patella (2). In professional athletes, two series of knee magnetic resonance imaging (MRI) in asymptomatic professional basketball

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players revealed an incidence of abnormal chondral signal in 57% of all players, with 35% having high grade patella signal and 25% with high grade trochlea signal (3,4). The key point to recognize is that the vast majority of chondral/osteochondral lesions are asymptomatic and should be observed, but not aggressively treated. While indications continue to evolve, there is no clear role for prophylactic cartilage restoration in the setting of asymptomatic lesions. In contrast, large and/or full thickness lesions with localizing symptoms (that have failed non-surgical optimization), especially in the setting of obvious pathoanatomy and aberrant biomechanics, require treatment of both the lesion and underlying co-morbidity.

Clinical evaluation

Patients do not initially present complaining of a chondral lesion. Their chief complaints are pain with PF loading, swelling, and a subset have patellar instability. It is the physician who must be suspicious that the symptoms may be in part due to PF chondral lesion(s). As with all patient problems, the first step is a comprehensive history. Care should be taken to elucidate whether complaints are primarily pain or instability, and if pain, localization is critical. Global pain is a red flag for debilitation, overuse, and variants of complex regional pain syndrome or secondary gain. Cartilage restoration is not part of these patients' treatment. Activities and their relation to pain should also be investigated. Patients should be queried for the presence of activity related effusions and/or mechanical symptoms of catching or locking. The overall mental state of the patient should also be assessed. It has been shown that patients with a positive outlook and mindset about life as measured by Short Form 36 (SF-36) tend to have better outcomes (5). Documenting prior treatments and the response to them is essential to understanding the underlying pathology. Documenting family history of ligamentous laxity or any musculoskeletal disorders is important.

The physical exam should begin with observation of the patient's gait and limb alignment, followed by stepping up and down evaluating both the arc of pain and any pelvic drop (indicative of hip/pelvis weakness) or dynamic valgus positioning. Seated evaluation is useful for patella height, Q-angle estimate, assessment of patella tracking via J-sign, and crepitus through a ROM arc. Quadriceps lag based on pain, apprehension, or weakness should be noted. Supine evaluation can localize tenderness to palpation, effusion, ROM, muscle bulk and tone, and soft tissue balance/ligament integrity. Patella mobility, as described by the quadrant method, should be documented and compared to the contralateral side (6,7). Medial to lateral mobility is tested at 0, 30, and 60 degrees in Fairbank's position (the patient is in the supine position with the leg abducted; lateral pressure is applied to the patella as the knee is flexed) to assess the competence of medial soft tissue restraints (i.e., MPFL, MPTL). Lateral retinacular tightness, fixed patella tilt, or iatrogenic or idiopathic lateral retinacular incompetence (i.e., hyperlaxity, prior lateral release) are assessed on the lateral side of the knee. Prone examination allows for evaluation of femoral/hip anteversion, tibial torsion, and thigh-foot axis.

Standard initial radiographs include bilateral comparison weight bearing anteroposterior, PA flexion (45° PA), 30° flexion true lateral, and low flexion angle axial views such as Merchants (*Figure 1*) (8). A hip-to-ankle view allows measurement of coronal plane mechanical axis alignment (i.e., varus, valgus deformity), which may play a role in PF tracking. AP and PA flexion views assess the tibiofemoral joint space. Axial and lateral views help assess patellar height and morphologic features such as trochlear dysplasia (i.e., crossing sign, supratrochlear spur, double contour) and patella tilt. Caton-Deschamps or Blackburne-Peel ratios are the current patellar height measurements of choice as they change with tuberosity surgical movement unlike the Insall-Salvati (*Figure 2*).

Advanced imaging typically includes MRI and/or CT scans. Standard sequences on 1.5T or 3T MRI are typically sufficient; however, cartilage specific sequences or specialized techniques may be useful adjuncts in specific challenging situations. MR arthrogram is rarely additive, but CT arthrogram can be useful in the assessment of OCD lesion stability. It is important to recognize that measurement of key alignment parameters vary from MRI to CT (9). In addition to comprehensive evaluation of the PF joint, MRI gives knowledge on the status of the medial/lateral compartments, other ligaments, menisci, and helps rule out other pathology (i.e., tumors, avascular necrosis, tendinopathy). MRI is useful to investigate the status of the underlying subchondral bone. The presence or absence of bone marrow lesions (BMLs) suggests bone

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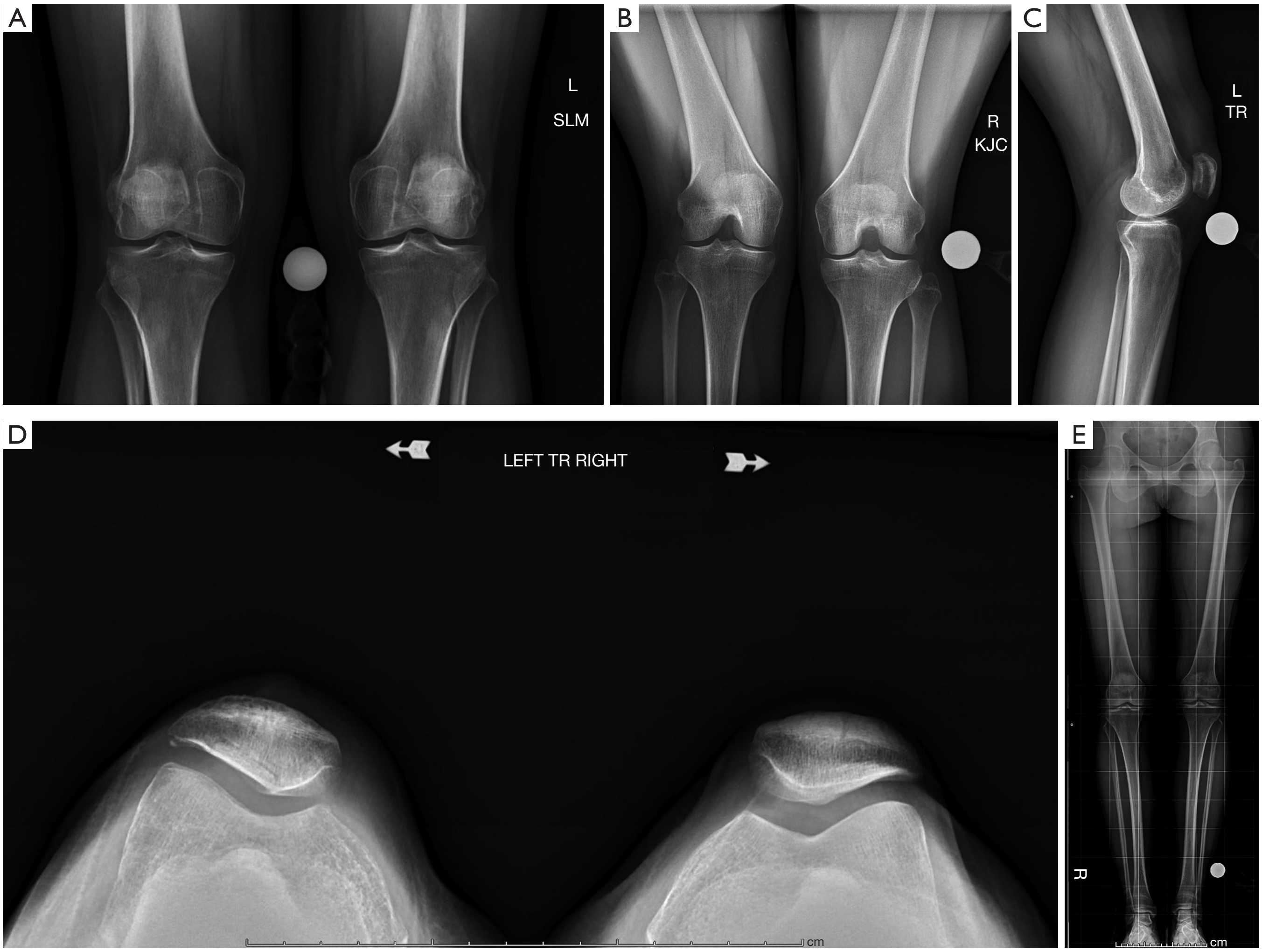

Figure 1 Standard initial radiographs include (A) bilateral comparison weight-bearing anteroposterior, (B) posteroanterior flexion (45° PA), (C) 30° fixed flexion true lateral, (D) low flexion axial view such as Merchants, and (E) long leg hip-to-ankle alignment.

overload through malalignment and/or loss of chondral protection. Specific to the PF joint, MRI gives a plethora of information including soft tissue competence, chondral status, trochlear morphology, presence of loose bodies, acuity of injury (i.e., bone bruise pattern), and alignment parameters in multiple planes. A portion of each image read is the tibial tubercle-trochlear groove (TT-TG) distance (which is not possible with a flat or convex trochlea) and the tibial tubercle-posterior cruciate ligament (TT-PCL), which is possible even with trochlear dysplasia (*Figure 3*). Noyes reported the method for using MRI cuts through the hip, knee, and ankle for measuring femoral anteversion and tibial torsion while avoiding the ionizing radiation of CT.

While knowledge of the average and recommended threshold values for each imaging measurement is a useful "starting place," no one value should be relied upon for clinical decision making. For example, several studies have shown that the TT-TG measurement has significant variation and several limitations, especially in the setting of trochlear dysplasia (10,11). Also, MRI typically underestimates the TT-TG compared to computerized tomography (CT) (9). Applying the patient's specific parameters to published normative and pathologic values will aid the surgeon in understanding the pathology and formulating a rational plan. That is, the treatment plan is made for an individual patient, not specific numbers.

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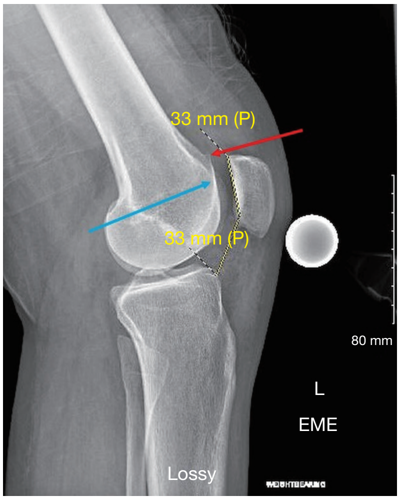

Figure 2 Lateral X-ray demonstrating measurement of patella height using the Caton-Deschamps method. Blue arrow points to the crossing sign and red arrow points to supratrochlear spur, both indicative of trochlea dysplasia.

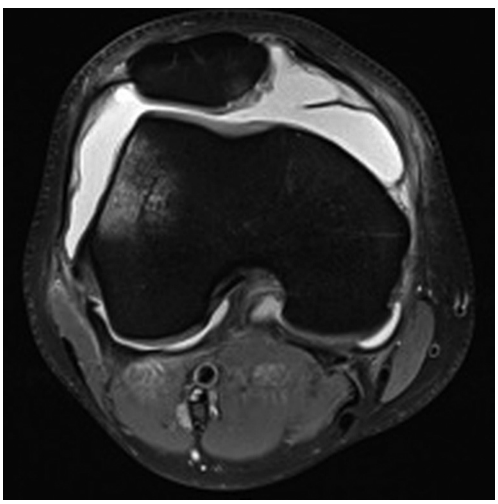

Figure 3 Axial MRI demonstrating medial cartilage lesion in a patient with recurrent lateral patella dislocations.

Conservative treatment

Non-operative management is preferred for the vast majority of chondral/osteochondral lesions in the PF joint. Following acute injury or in the presence of chronic, insidious symptoms, activity modification is important to rest the joint and to avoid further harm from overload. Medical and/or biologic injections may be helpful, when indicated, to reduce pain so that the patient may rehabilitate successfully. Nonsteroidal anti-inflammatory drugs medications, Tramadol, and/or Tylenol can be useful agents; narcotic medications are not indicated for the non-operative management of PF chondral/osteochondral disease in most cases although tramadol can be used in certain cases for short periods of time. Alternative modalities may be considered for a multi-modal approach to pain management (i.e., transcutaneous electrical nerve stimulation, localized creams, patches, injections). If corticosteroid injections are indicated for acute/subacute flair (i.e., painful effusion), they should be used sparingly, especially in younger patients, due to concerns over deleterious effects on articular cartilage over time (12). Several studies have shown that local anesthetics (i.e., 1% Lidocaine) are chondrotoxic and should be avoided. A corticosteroid such as Kenalog, however, has demonstrated no significant negative effect on chondrocyte viability, and may be utilized in a saline vehicle. Efficacy of viscosupplementation remains controversial, but it is safe for articular cartilage and can be considered (13,14). It is critical to recognize that not all viscosupplements are the same. In general, we prefer higher molecular weight hyaluronic acid preparations formed through bacterial fermentation, which have demonstrated efficacy versus other agents. Injection of platelet rich plasma has gained interest with a growing body of literature support. This has shown promise, especially with leukocyte poor formulations, but definitive evidence is still lacking (15-19). Other injection agents (i.e., amniotic fluid/cells) are similarly promising, but expensive and continue to be under clinical investigation.

Rehabilitation is the key component to any plan for the PF joint. A comprehensive "core-to-floor" rehabilitation plan should be undertaken to correct any underlying muscular weakness and/or neuromuscular imbalance (20). Physical therapy, focusing not only on quadriceps strengthening, but also paying attention to the core and posterior chain musculature (i.e., gluteus, hip external rotators, hamstring), should be the first line treatment. Hamstring:quadriceps ratio should be optimized to reduce loads on the knee joint during joint activity. Proprioception and flexibility training can also help to improve symptoms. There is limited evidence for or against patellar stabilization braces or compression sleeves. Braces may be useful after acute patella dislocation and/or surgery and sleeves may help with proprioception and swelling during the rehabilitation process (21).

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Surgical indications

In general, non-surgical treatment is the rule for the majority of PF conditions, including chondral/osteochondral lesions. Surgery should only be considered if patients have persistent or worsening symptoms despite improvements in dynamic strength, flexibility, and neuromuscular status (8). Early surgical intervention is recommended for acute chondral/osteochondral injury with displaced fragment, which often occurs following patella dislocation or traumatic impaction injury (21,22). Early surgery is similarly warranted for patients with symptomatic, unstable OCD lesions. Good results have been shown even in fixation of purely chondral fragments (23). Surgical indications for patella instability follow current recommended guidelines (i.e., risk factor stratification for first time dislocators, surgery for recurrent dislocators, or patients with subluxation events or habitual/fixed dislocation that have failed conservative treatment). The need for treatment of concomitant cartilage lesions during patella instability surgery will be discussed in a later section.

Otherwise, for the majority of cases of PF chondral/osteochondral lesion(s) and/or underlying malalignment, failure of up to 6 months of conservative treatment is warranted. In these patients with persistent painful effusion and localizing mechanical symptoms effecting daily life and quality of life, surgery may be considered. A thorough pre-operative conversation should be undertaken with the patient as to realistic expectations for the final outcome possibilities as there is always a range from excellent to frank failure. Unlike PF conditions that may likely lead to a "normal" outcome with return to unrestricted activity (i.e., isolated MPFL reconstruction), cartilage repair patients often have complex and multifactorial presentation. Success for cartilage restoration patients often includes reduction of pain, improvement in ADLs, ability to return to occupation, and low impact sporting activities. Secondary goals over time may include return to full sports, but this is often not expected in the majority of patients and never promised. Nonetheless, the majority of well-selected surgical patients improve with treatment, but likely have some sort of permanent activity restriction (24).

Risk factor modification is critical prior to surgery. Patient specific factors such as body mass index (BMI), tobacco use, chronic pain management, and diabetes may affect the overall outcome and should be addressed prior to recommending surgery. Smoking certainly is detrimental to any surgical procedure; studies to date have been unclear as to the exact outcome of nicotine on chondral restorative procedures. However, many surgeons view the use of tobacco as a contraindication to cartilage restoration (25). BMIs above 35 may also result in early failures (26).

Concomitant procedures

When addressing chondral pathology, all underlying abnormal biomechanical factors need to be evaluated for correction either in a staged fashion or concomitantly. That is, a TT-PCL of 26 and patellar height of 1.3 are out of the normal envelope, but a risk/reward assessment for a particular patient may or may not suggest these should be treated surgically at the time of cartilage restoration. Regardless of a one- or two-step approach, diagnostic arthroscopy should be performed to assess chondral surfaces and patella tracking. Examination under anesthesia should be performed to assess tibiofemoral ligamentous stability as well as that of the patella soft tissue envelope. The affected side should be compared to the contralateral limb. During arthroscopy, the location, dimension, and chondrosis grade is documented along with the tibiofemoral compartments. The intra-articular tracking of the PF joint should also be assessed under low inflow or air-only conditions.

The combination of pathology location and tracking will allow titration of the treatment algorithm. Maltracking and instability will need to be fully assessed and a comprehensive plan developed prior to or simultaneously with any chondral procedure. This could include even femoral or tibial derotational osteotomies. Tuberosity realignment may aid in normalizing abnormal loading parameters, but one should be aware of the effects of shifting loads, as studied by Pidoriano *et al.* (27). For example, a standard anteromedialization (AMZ) of the tibial tubercle moves loading forces proximal and medial on the patella. Patients with malalignment and distal/lateral patella or trochlea chondral lesion(s) may be successfully treated with isolated AMZ, negating the need for cartilage restoration. Similarly, patients with medial or pan-patella chondral disease do poorly with isolated AMZ, as it overloads the lesion. When performing realignment for these patients, concomitant cartilage restoration is indicated to optimize outcome. Lastly, realignment may be deferred altogether when treating impaction type chondral injuries

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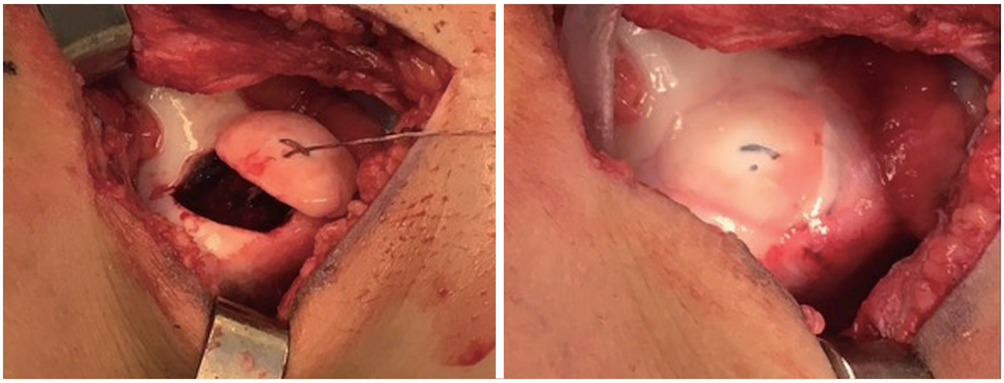

Figure 4 Unstable OCD fixation in patellofemoral compartment. OCD, osteochondritis dissecans.

of the proximal pole or medial patella lesions resulting from patella dislocation. Soft tissue stabilization (i.e., MPFL, MPTL reconstruction) is indicated for patients with patella instability. Other procedures, such as lateral releases *vs.* retinacular lengthenings (or even retinacular reconstructions), should be undertaken as dictated by physical examination parameters in conjunction with chondral pathology. Trochleoplasty for trochlear dysplasia is reserved for advanced trochlear dysplasia and even advocates state it is contraindicated if significant chondrosis is present.

Chondral procedures

A summary of the outcomes of cartilage restoration procedures for the PF joint may be found in *Table S1*.

Debridement

Debridement as an isolated treatment has become more difficult to apply as insurance medical policies cite studies primarily investigating arthritic conditions in the tibiofemoral compartment that show no improvement over non-operative management. However, these conditions are not equivalent to unstable chondral lesions in a non-arthritic joint. Chondral lesions often have unstable tissue, which may be conservatively stabilized with an oscillating shaver; unstable flaps can be resected and stable vertical walls of healthy adjacent cartilage can be created with a curette when the lesion is full thickness. Until there is universally accepted evidence that electrical debridement is full chondral safe in all hands, it is not recommended. Chondroplasty affords the quickest recovery, as there are typically no weight bearing restrictions, no bracing, and patients can return to activities without limitations during recovery. Debridement is the surgical treatment of choice for unstable, small (<2 cm^2), partial or full thickness lesions in low demand patients or in patients who are not good candidates for more complex cartilage restoration pathways (i.e., obesity, non-compliant) (28). For larger, unstable lesions in high demand patients, debridement may be performed for mechanical symptoms at the time of staging arthroscopy alongside biopsy for future cell based cartilage transplantation.

Internal fixation

Traumatic patella instability episodes may result in chondral or osteochondral shear injuries to the medial patella, lateral trochlea, and/or lateral femoral condyle. Alternatively, unstable OCD lesions may similarly present with pain, swelling, and mechanical symptoms. A potentially fixable loose osteochondral body in the setting of a first-time PF dislocation or idiopathic OCD is an indication for early surgery (*Figure 4*). In skeletally immature patients, internal fixation of chondral only fragments may be attempted with sutures or suture anchors with reasonable success rates (29,30). Osteochondral or chondral loose bodies that result from recurrent patella instability or from longstanding OCD in skeletally mature patients may not be repairable. In these patients, excision is the preferred option, with careful determination of the size, depth, and location of the chondral injury for potential future cartilage restoration procedure.

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Marrow stimulation techniques (MST)

These include abrasion arthroplasty, microfracture, drilling or nanofracture techniques. The premise of treatment is replacement of deficient articular hyaline cartilage (type II collagen) with fibrocartilage (type I collagen) formed after maturation of marrow elements released from beneath the subchondral plate. Abrasion arthroplasty removes a superficial layer of the subchondral bone exposing vasculature, whereas the other techniques make penetrations of varying size and depth deep to the subchondral plate to access marrow elements. In general, microfracture outcomes are best in small (<2 cm^2), contained, acute or subacute surface lesions in young patients (31-33). Despite studies demonstrating deteriorating results over time, microfracture remains the standard by which other chondral restorative procedures are compared for femoral lesions in FDA approved clinical trials. There have been no FDA trials in the PF joint for cartilage restoration products. However, most studies show deterioration within 18–36 months and PF lesions did significantly worse (33). It may be reasonable to consider trochlea marrow stimulation arthroscopically, particularly for small and contained lesions in low demand patients. For patella lesions, the combination of poor results and requirement of at least a mini-arthrotomy for technical execution makes this a less desirable treatment option. Additionally, microfracture can damage the underlying subchondral bone and is associated with intra-lesional osteophyte formation in a percentage of treated patients. This plays a role in the 3× higher failure rate of cell based cartilage repair following microfracture when compared to primary treatment of a lesion (34,35). Evolving techniques utilize narrower and deeper instruments and/or augmentation of MST with scaffolds (autologous matrix induced chondrogenesis, AMIC) may help to address these underlying issues (36-39). However, to date, MST remains a fibrocartilaginous repair with persistent doubt regarding repair strength and durability for most PF lesions (40).

Cell based repair

Cell based cartilage repair is a time-honored treatment for symptomatic, large, contained lesions of the patella and/or trochlea without bone loss. Several long-term studies have demonstrated efficacy of cell based repair in the PF joint, making it a first-line workhorse for solitary, bipolar, or multifocal lesions on either side of the joint. Benefits include preservation of bone stock, relative technical ease, ability to match complex PF topology; drawbacks include typical need for 2-stage surgery, prolonged and complex rehabilitation, need for remodeling and maturation *in vivo* (18–24 months), and expense. Treatments discussed below include matrix autologous chondrocyte implantation (MACI®, Vericel, Cambridge, MA) and particulated juvenile allograft cartilage (PJAC) (DeNovo NT®, Zimmer Biomet, Warsaw, IN).

ACI/MACI

Histologic studies have shown that autologous chondrocyte implantation (ACI) (and by extension MACI) results in hyaline-like Type II collagen (41). ACI has the most data to support its use compared with the other techniques; however, use on the patella was considered off-label in the US based on the FDA conditional biologics license applications (BLA) issued in 1997. The BLA was issued based on the Brittberg *et al.* initial study of ACI (42). While femoral lesions had acceptable outcomes, the few patients with patellar lesions showed poor results (42). However, malalignment was not addressed in this initial patient cohort. When bony alignment and other co-morbidities were corrected concurrently or in a staged fashion, results by the same authors were shown to be similar to femoral lesions of the knee (43). Subsequent authors corroborated this (44,45). Poorer results were seen in ACI performed as revision surgery for failed microfracture compared to those performed as the initial index procedure (34,35). MACI was approved by the FDA in 2017 and is indicated for use in all compartments of the knee as a primary treatment option. Studies of MACI also show PF results which are comparable to the tibiofemoral results when appropriate concomitant procedures are performed (46,47). Filardo *et al.* have shown the difference in outcomes between patellar and trochlear lesions when treated by MACI (48). ACI is no longer available for commercial use as it has been replaced by MACI. Some studies have shown a tendency towards better results with MACI compared to ACI for the PF joint (*Figures 5,6*) (49,50).

PJAC

DeNovo NT has neither randomized controlled trial nor long-term data at present. However, preliminary outcomes are promising. The first report on DeNovo NT in patellar chondral lesions showed significant improvements in MRI scores, functional scores, and

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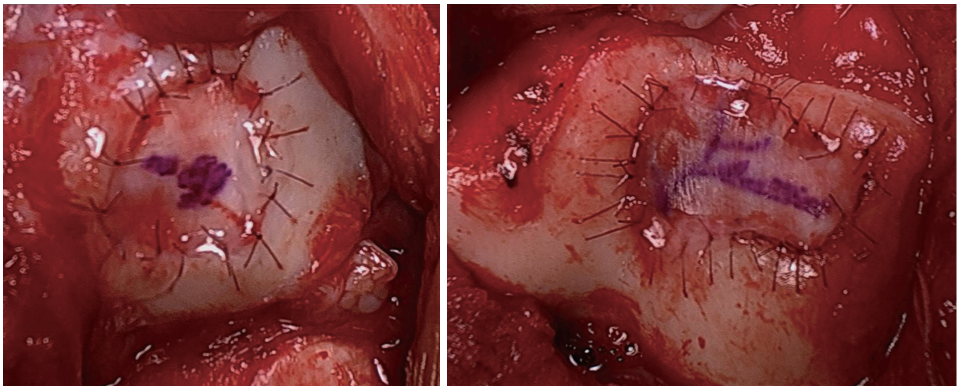

Figure 5 ACI for bipolar PF compartment chondral lesions. ACI, autologous chondrocyte implantation; PF, patellofemoral.

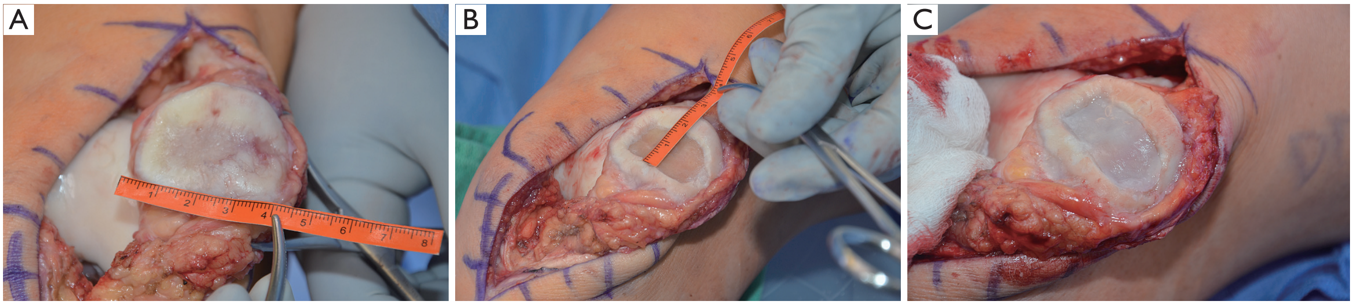

Figure 6 MACI for the patellofemoral joint. (A) Defect prior to preparation; (B) defect after preparation down to subchondral bone; (C) membrane implanted into defect.

pain scores at over 2 years follow up (51). A recent MRI study out to two years showed that lesion fill at 6, 12, and 24 months was 82%, 85%, and 75%, respectively (52). Clinical outcome measures were not reported in this study. Other studies have shown that imaging results do not necessarily correlate with clinical outcomes (53). Buckwalter *et al.* did present clinical outcomes of DeNovo NT in patellar lesions at an average of 8.2 months; significant improvements in KOOS scores were seen with a trend towards improvement in KOOS subset scores (54). A 2-year prospective trial showed improvements in clinical scores, radiographic appearance, and even histology of tissue in the defect (55). Advantages of DeNovo NT include the ability to perform implantation in a single surgical setting as well as the use of immature chondrocytes, which have been shown to have increased metabolic and proliferative activity when compared to adult chondrocytes (*Figure 7*) (56).

Osteochondral treatments

The two main treatments in this category are osteochondral autograft transplantation (OAT) and osteochondral allograft (OCA) transplantation. Both of these share the benefit of the ability to replace diseased subchondral bone, making them useful in cases of compromised bone bed (i.e., OCD, prior microfracture, uncontained lesions, subchondral cystic changes, AVN) and in revision. Benefits include the transplantation of mature, hyaline cartilage at time zero; drawbacks include donor site limitations and morbidity for OAT and graft matching, availability/viability, technical difficulty, and expense for OCA.

OAT

OAT in the PF joint is challenging due to the difference in patellar cartilage thickness, typical donor sites (trochlea), and the complex nature of the anatomy. The size of the

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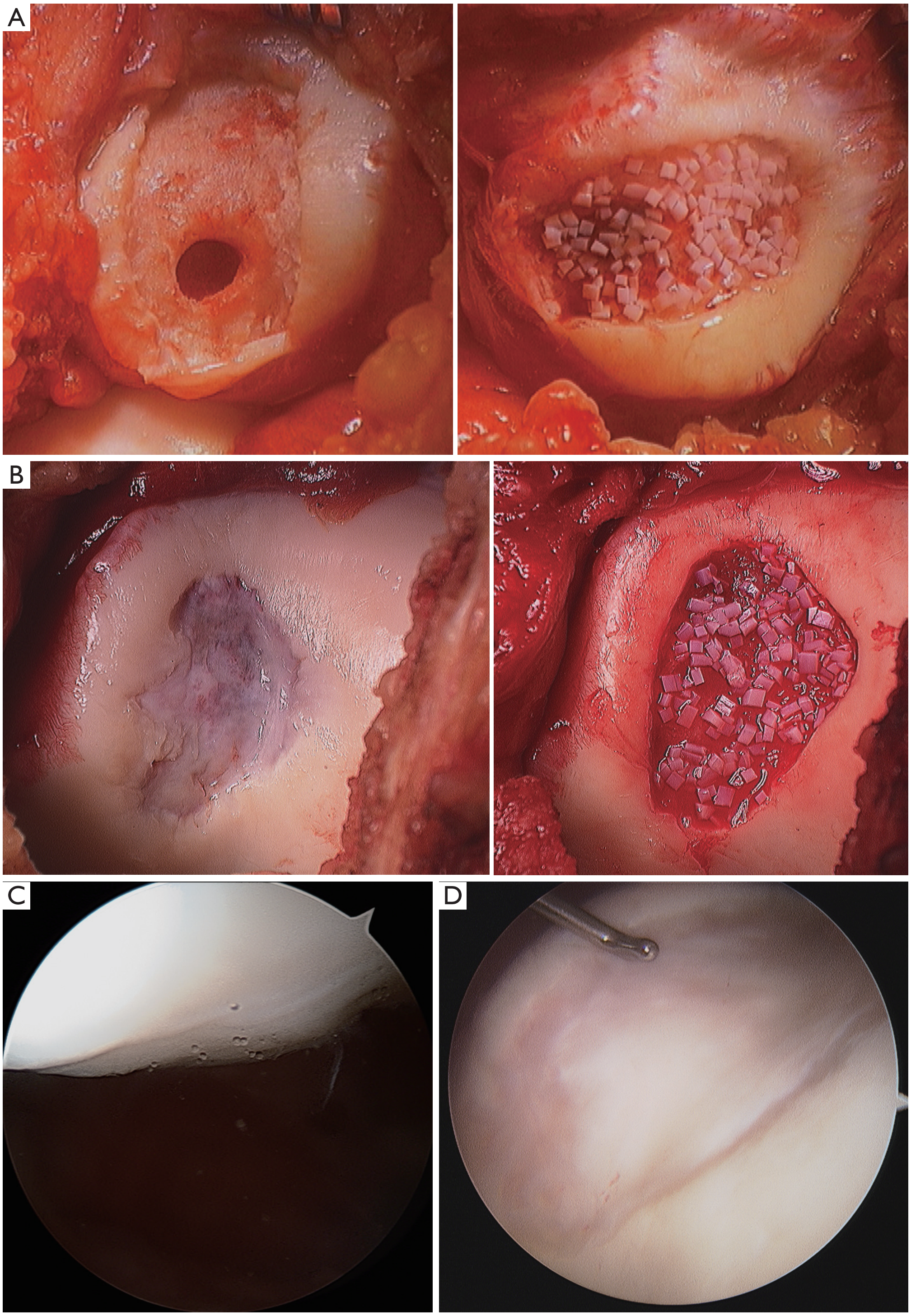

Figure 7 DeNovo NT for the PF joint. (A) Patella lesion with bony defect treated with autologous impaction bone graft and DeNovo NT in single-step procedure; (B) trochlear lesion treated with DeNovo NT; (C) three years postoperative second-look arthroscopy of patellar DeNovo NT implant; (D) fifteen months postoperative second-look arthroscopy of trochlear DeNovo NT implant.

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lesion also limits the use of this technique, as increasing the number of plugs harvested also increases the risk of creating donor site (trochlea) morbidity (57,58). That is, harvesting trochlea OAT plugs for a patella lesion in patients with PF symptoms is a concern. However, OAT is advantageous in rare situations for small, focal chondral or osteochondral lesions because it can be done in a single surgery. Use of autogenous tissue also has the advantage of minimizing the chance of bony junction integration failure, as well as minimizing costs. A 2-year outcome study of PF lesions between 1–2.5 cm^2 demonstrated significant improvements in functional outcomes. Integration was reported at 83% 6 months after surgery, and 100% at 1-year post-implantation. It was also noted that patients receiving one plug fared better than patients that received two plugs, and that lateral plugs had significantly better outcomes than those with medial and lateral plugs. Central lesions were excluded from the study (59). Figueroa *et al.* conducted a prospective case series of OATS in the patella and saw improvements in clinical, functional, and radiographic parameters (60). Nho *et al.* also found good results with OAT in the patella, but found that the subset with concomitant maltracking (even though corrected) did not fare as well as those without maltracking (61).

OCA

There are numerous allograft types, ranging from fresh viable OCA, cryopreserved, and off-the-shelf non-viable options. Fresh stored OCA is the preferred technique. OCA may be used for large and uncontained lesions, as donor site morbidity is not an issue with these cases. However, drawbacks include size matching and availability of donors and the very low risk of disease transmission. Also, newer techniques for graft storage have the ability to expand the lifespan and cell viability of grafts, effectively increasing the donor pool (62,63). Another significant risk is failure of graft incorporation. The osteochondral unit is essentially an immune privileged entity, so rejection in the sense of solid organs is not an issue, obviating the need for anti-rejection medication; however, the donor bony tissue may not become fully integrated into the recipient osteology. This can be mitigated by thoroughly pressure irrigating the bone of the OCA to remove donor stromal elements. Additionally, modalities to augment osseous substitution and integration, such as with bone marrow aspirate concentrate, have shown early promise (64).

In the past, allograft transplantation to the PF joint has had poorer outcomes when compared to transplantation to the condyles due to the unique morphology (65); however, modern techniques have significantly improved outcomes. Bugbee's group has shown over a 91% survivorship at 10 years for isolated trochlear OCA, with 89% satisfaction (66). The same group also showed 78% survivorship at 5 and 10 years for isolated patellar OCA, with 55.8% survivorship at 15 years, and satisfaction was reported at 89% (67). Additionally, it has also shown favorable results in the case of bipolar lesions, albeit with higher rates of failure than monopolar lesions (68). OCA can be particularly helpful in revision situations and in conditions where the underlying subchondral bone is compromised (69). It is also a preferred technique over cell based cartilage repair in patients with early osteophytes, early joint space narrowing, increasing age, and elevated BMI. Torga Spak and Teitge showed good results for OCAs performed for PF arthritis (70). Fixation for OCA is myriad; for the simple dowel technique, press fit is often all that is required whereas more complex geometries may utilize a shell allograft technique and thereby require fixation with a combination of non-absorbable and absorbable materials (*Figures 8,9*).

Arthroplasty

PF arthroplasty is reserved for older, lower demand individuals or for those that have failed all other restoration type procedures. Outcomes are fairly predictable and are typically good if mechanical alignment is corrected (71). Patients with history of post-traumatic PF arthritis typical fare better than patients with insidious onset of tricompartmental osteoarthritis, first presenting in the PF joint. Recovery is typically quicker than a chondral procedure, usually with weight bearing as tolerated, range of motion as tolerated, and no use of a brace.

Conclusions

The treatment of PF chondral lesions is complex and multifactorial. The vast majority of lesions are asymptomatic and require no specific treatment. Non-operative management is the rule for the majority of symptomatic chondral lesions. When surgery is indicated, treatment choice is dictated by lesion characteristic (i.e., size, location, depth) and by patient, joint, and limb specific parameters. Optimization of the joint environment by concomitant bony and/or soft tissue procedures is critical to success. With careful pre-surgical

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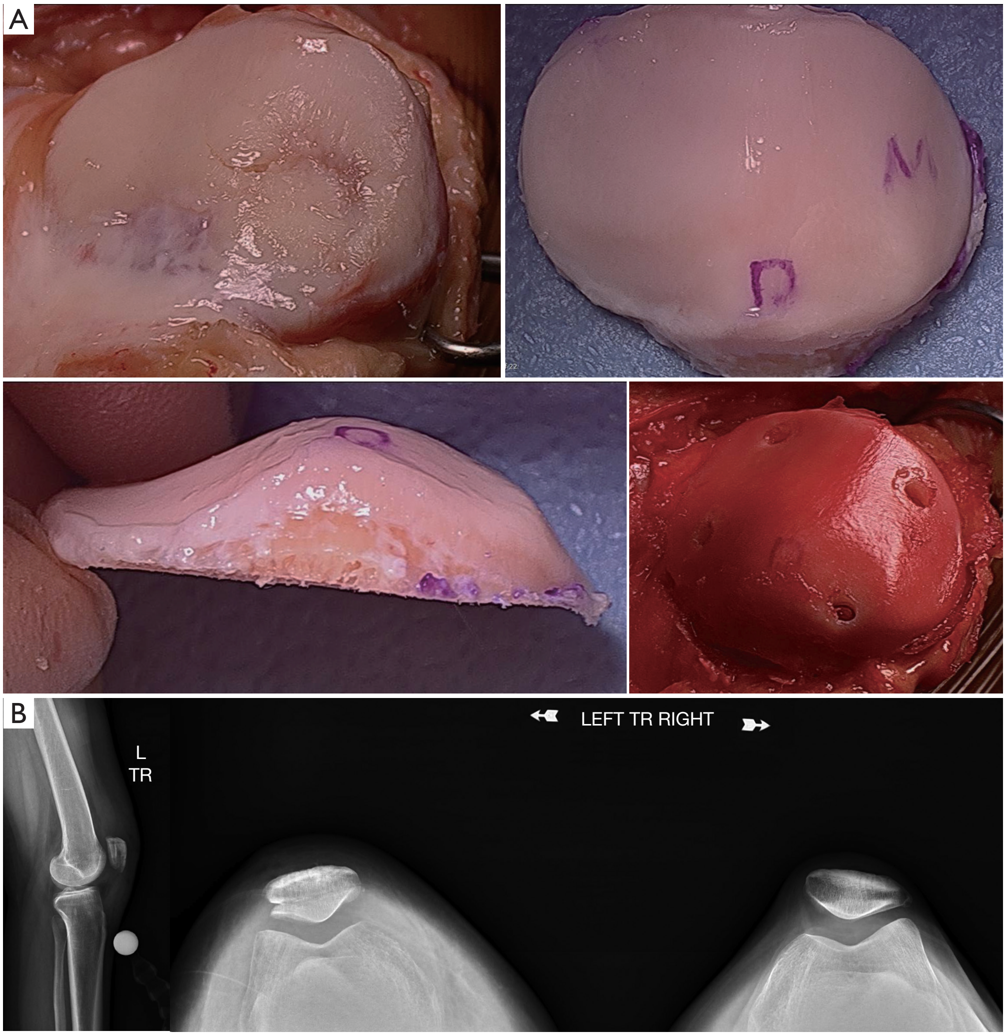

Figure 8 OCA shell for patellar defects involving both the medial and lateral facets. (A) Osteochondral allograft shell fixed with 4 bioabsorbable screws; (B) one year postoperative lateral and merchant radiographs demonstrate bony healing and joint space maintenance.

planning, meticulous technique, and compliance with a post-operative rehabilitation program, good to excellent outcomes may be achieved. Patient counseling is important to provide realistic goals and expectations.

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Footnote

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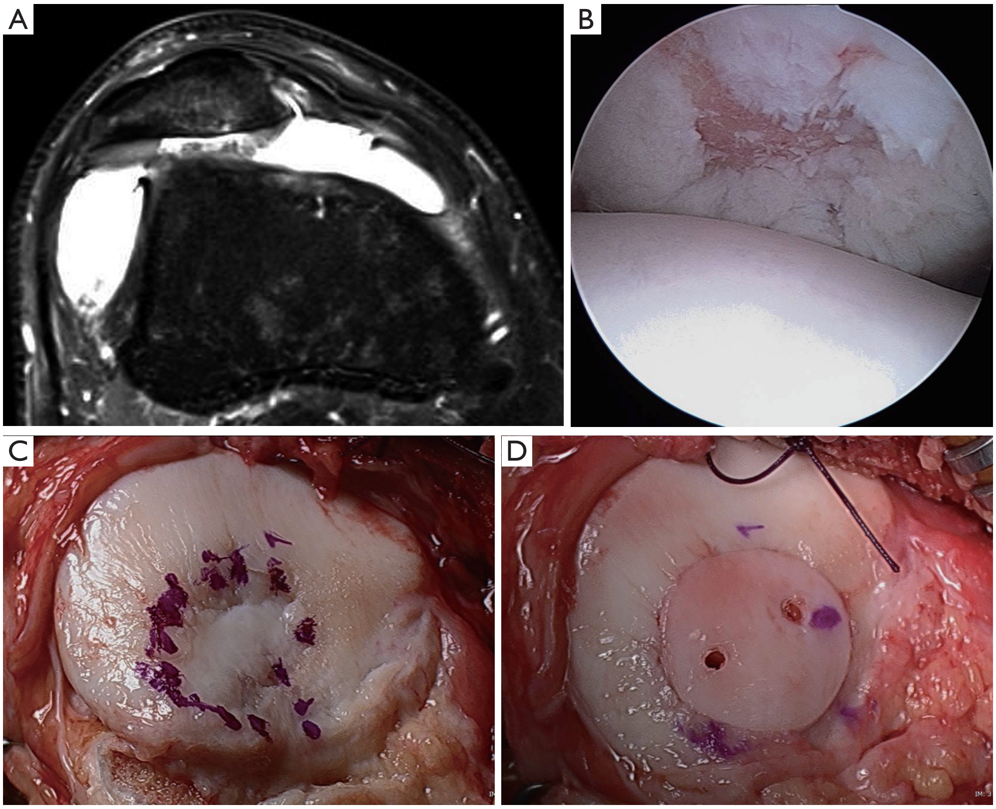

Figure 9 OCA for patellar chondral defect with subjacent bone marrow lesion. (A) T2 fat suppressed axial image of patella demonstrating defect and associated bone marrow lesion; (B) staging arthroscopy of grade 3C lesion; (C,D) osteochondral allograft plug fixed with 2 bioabsorbable screws.

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Table S1 Outcomes of patellofemoral cartilage restoration

Study	Design	Defect characteristics	Follow-up	Results	Conclusion
MST					
Microfracture					
Mithoefer (31)	Systematic review; 28 studies, N=3,122. Patella, trochlea, condyles	Mean size 3.0± 0.8 cm^2 (range, 0.1–20 cm^2). Patella, trochlea, condyles	Mean 41±5 mo (range, 12–136 mo)	Knee function improved 67–86% at 6–7 y. Longest study: 32% pain free, 54% mild pain, 14% moderate pain (11 y follow/up). Failure/revision: 2.5% at 2 y, 23–31% between. 2–5 y (in 6 RCTs)	All studies showed improvement in knee function at 2 years. Defect fill on MRI correlated with outcome
Gobbi (32)	Retrospective review; N=67 with 61 athletes available at final f/u	401±27 mm^2. 41 patients with single lesion. 14 patients with PF lesions, with 10/14 with multiple lesions	Average final f/u at 15.1 years	IKDC, Lysholm and Tegner scores increased significantly at 2 years, but gradually deteriorated at long term. Average scores were significantly above baseline at final follow-up. 11% failure rate due to re-injury or persistent pain	Knee scores improved significantly by 2 years but began to decline after. Knee scores should be expected to decline between years 2 and 5. Lesions less than 400 mm^2 in size had better results. 40% of knees had radiographic evidence of osteoarthritis at final f/u with older patients and those with larger lesions having a significantly greater rate of arthritic progression
Kreuz (33)	Prospective study; N=70 with average age of 39.5. Used Cincinnati knee and ICRS scores	Trochlea 2.31 cm^2 (range, 1–4 cm^2) and patella 2.0 cm^2 (range, 1–3 cm^2). 32 condyles, 11 tibia; 11 patella and 16 trochlea	Final f/u at 36 months, with evaluations preop, 6, 12, 18 months	All groups showed significant improvement in scores from pre-op to final f/u. ICRS scores deteriorated by 36 months in all groups. Trochlea, tibia, and patella lesions also had Cincinnati scores significantly decrease between 18 and 36 months	Condylar lesions in younger patients have overall best outcomes. MRI fill at 36 months is significantly better for condylar lesions
Minas (34)	Cohort study using prospectively collected data. N=321 (325 knees), divided between prior MST (N=111) and control (N=214)	Control size 4.6±2.7 cm^2 (range, 0.5–21 cm^2). MST 5.2±3.1 cm^2 (range, 0.7–16.8 cm^2)	Average 55 mo. Control: 54 (range, 24–132) and MST 56 (range, 24–144)	There was a 26% failure rate in the prior MST group (defined as need for removal of over 25% of grafted area due to persistent symptoms) compared to an 8% failure rate in the other 214 joints	There was no statistical difference between different failure rate of MST technique (Microfracture, abrasion chondroplasty, drilling). Alteration of the subchondral bone leads to 3x the failure rate of ACI when performed for prior MST *vs* index. This was consistent across location.
AMIC					
Kusano (36)	Retrospective. N=40 knees in 38 patients; 20 patella, 9 condyle, 11 OCD condyle	Mean size condyle: 2.3±0.4 cm^2. Mean size patella: 4.4±0.6 cm^2. Mean size OCD condyle: 4.2±0.4 cm^2	28.8±1.5 months (range, 13–51 months)	Significant improvements in clinical outcome scores (IKDC, Lysholm, Tegner, and VAS pain). More improvements noted in osteochondral lesions on the condyle for OCD. AMIC alone and AMIC in combination with unloading osteotomy or patella realignment significantly improved symptomatic knees with isolated osteochondral and chondral lesions in the knee joint	AMIC is a safe procedure and leads to clinical improvement of symptomatic full-thickness chondral and osteochondral defects and to regenerative defect filling. More improvement for osteotomies when lesions were OCD or in the patella
Gille (37)	Cohort, multicenter. N=57	3.4 cm^2 (range 1–9 cm^2)	2 years	Significant decrease in VAS: preop =7.0; 1 year postop =2.7; 2 years postop =2.0). Significant improvement of the mean Lysholm score was observed as early as 1 year after AMIC and further increased values were noted up to 2 years postoperatively (preop. 50.1, 1 year postop. 79.9, 2 year postop. 85.2)	Need longer term studies for durability. AMIC is an effective and safe method of treating symptomatic chondral defects of the knee. Did not compare outcomes based on lesion location
Gille (38)	Prospective. N=32 lesions in 27 patients	4.2 cm^2 (range 1.3–8.8 cm^2)	Mean 37 months (range, 24–62 months)	The Lysholm score and the IKDC score showed both for cartilage defects situated at the patella and medial femur condyle a significant increase in values up to 24 months. Values at 36 months decline significantly in the group of defects at the patella, but not at the femoral condyle. 15 patients with MRI at final f/u. 10 had filling of >50%. 7 bone marrow lesions, 8 effusions, and 9 instances of osseous hypertrophy under the graft were found	AMIC safe and effective. Need longer term studies. Drop off in scores at 3 years for patella lesions whereas no drop noted for condyle lesions
Panni (39)	Retrospective. N=21	4.3 (range, 2.9–8) cm^2	7±1.4 years	IKDC score improved from 31.7 ±8.9 points preoperatively to 80.6 ±5.3 (P<0.05) post-op. The mean Lysholm score improved from 38.8±12.4 points preoperatively to 72.6 ±19.5 (P<0.05) postoperatively. 2/3 of patient with good quality repair tissue on MRI. 76.2% patients satisfied or extremely satisfied. Significant improvements in functional scores at 3 years were maintained at 7 years	AMIC able to handle lesions >2 cm^2 with good results. Outcomes are durable past 2 years, with improvements maintained at final follow up of 7 years
ACI/MACI					
Brittberg (42); ACI	Prospective study. N=23. Post-op arthroscopy performed at 3 months, and 2nd look between 12 and 46 months. ACI, periosteal patch	Mean size 3.1 cm^2 (range, 1.6–6.5 cm^2). 13 femoral condyle, 3 OCD on condyle, 7 patellar lesions	Average 39 months (range, 16–66 months)	14/16 of femoral condyle patients had good-excellent results at 2 years. In patella lesions at 3 years, 2/7 had good-excellent results, 3/7 with fair results, and 2/7 with poor. Biopsies in 11/15 condylar transplants showed hyaline cartilage. Biopsy in 1/7 patella lesions showed hyaline cartilage	Patella lesions had disappointing outcomes whereas condylar lesions showed good results. 5/7 patella lesions had improved knee outcomes but only 2 with good to excellent results. Authors hypothesized that malalignment of patella could contribute to poor outcomes (no concomitant procedures performed ie tibial tubercle osteotomy)
Vasiliadis (43); ACI	Retrospective. N=92 patients (39 isolated patella, 8 isolated trochlea, 18 both patella and trochlea, and 27 multiple lesions including a patella or trochlea lesion)	Mean size =5.5 cm^2 (SD 2.9 cm^2), with a mean ratio of 1.7 lesions per patient	12.6 years (SD 2.3 years)	Median Tegner score =3, improved by one level compared with preoperative values (P=0.02). Median Lysholm score =70, improved by nine points (not significant). 72% of the patients were better or unchanged. 93% would undergo the operation again. Patients with malalignment or instability that had a realignment procedure of any form had comparable outcomes compared to the cases that did not need any additional surgery (n.s.). Monopolar lesions had better prognosis. Realignment procedures were associated with a decreased incidence of periosteal hypertrophy (16% in those with realignment procedures, 39% in cases without realignment procedures, P=0.01)	ACI provides good, durable, long term results. Chondral lesions in those with patellofemoral maltracking can have similar results to those with chondral lesions without maltracking provided the malalignment is corrected. Realignment surgery showed decreased patch hypertrophy by unloading the lesion but had higher rates of post-operative complications. Bipolar kissing lesions have the worst prognosis
Gillogly (44); ACI	Case series. N=25 knees in 23 patients. All patients had concomitant AMZ	Mean patellar defect size was 6.4 cm^2. 5 lesions uncontained. 52% (n=13) were type IVb (panpatellar involvement >80% of the surface)	Average 7.6 years (range, 5.1–11.4 years)	83% (19/23) reported good to excellent outcomes. 3 patients (13%) reported fair outcomes, and 1 patient (4%) reported a poor outcome. Ninety-one percent (21/23) of patients felt that their knee was improved from their preoperative status and would definitely or probably undergo the procedure again. 52% (12/23) reported an improvement in sports	Postoperative modified Cincinnati Knee Rating System and IKDC scores significantly improved from preoperative values regardless of lesion size/location and regardless of containment. Similar subgroup results were also observed for the Lysholm score and physical and mental component scores of the SF-12. Combined ACI and AMZ resulted in significant improvements in symptoms and function in patients with isolated symptomatic patellar chondral defects after a mean follow-up of more than 7 years
Gomoll (45); ACI	Prospective case series. N=110	All patients had patella defects. Average size 5.4± 2.7 cm^2 (range, 1–13.2 cm^2). Thirty patients (27%) had bipolar disease with trochlear defect, average size of 4.5± 2.8 cm^2 (range, 1–13 cm^2)	90±31.7 months (range, 48–192 months)	69% of patients with AMZ. IKDC: 40±14 → 69±20 (P<0.001). Cincinnati: 3.2±1.2 to 6.2±1.8 (P<0.001). WOMAC: 50±22 to 29±22 (P<0.001). 92% would undergo ACI again. 86% good or excellent results. 8% treatment failures. 16% no improvement	ACI is FDA off-label in the patella. No difference in outcomes with respect to lesion polarity, location, size, containment, or concurrent osteotomy. When performed with attention to patellofemoral biomechanics, self-rated subjective good and excellent outcomes can be achieved in more than 80% of patients treated with ACI even with large and bipolar defects. Final functional scores, although significantly improved, still reflected residual disability
Ebert (46); MACI	Prospective cohort study. N=194. 127 condyles (medial =94 and lateral =33). 67 to PFJ (patella =35, trochlea =32)	PFJ defect size mean 3.0 cm^2 (0.7–12.2). 26/67 PFJ patients with concomitant realignment (lateral release, TTO). PFJ group, extensor realignment subset had significantly (P=0.020) larger chondral defects at the time of surgery (mean size =3.4 cm^2) *vs.* those without realignment (mean size =2.7 cm^2)	Study followed out to 24 months	PF group had significantly lower values at baseline for the KOOS, activities of daily living, and quality of life subscales, it actually displayed a similar net improvement over time compared with the TF group. At 24 months, 93.7% (N=119) and 91.0% (N=61) of patients were satisfied with the ability of MACI to relieve their knee pain, 74.0% (N=94) and 65.7% (N=44) with their ability to participate in sport, and 90.5% (N=115) and 83.6% (N=56) satisfied overall, in the TF and PF groups, respectively. MRI scores improved over time. Subchondral lamina scored significantly better (P=0.002) in the TF group but subchondral bone scored significantly worse (P<0.001)	At 24 months, the overall MRI composite score was classified as good/excellent in 98 TF patients (77%) and 54 PF patients (81%). 90.5% (N=115) of the TF group and 83.6% (N=56) of the PF group were satisfied with the results. MACI in the PF joint with concurrent correction of PF maltracking if required leads to similar clinical and radiological outcomes compared with MACI on the femoral condyles
Ebert (47); MACI	Prospective cohort. N=47 (23 trochlea, 24 patella)	3.3 cm^2 (1.0–7.2)	24 months	KOOS, SF-36, VAS, 6-minute walk test, knee ROM, and strength all with significant improvement. Graft infill and the MRI composite score also demonstrated statistically significant improvement. 85% satisfied, 4.3% failure	MACI provides good clinical and radiological improvement in patients with patellofemoral articular lesions. Subgroup analysis for those with and without realignment osteotomy did not show any differences.
Filardo (48); MACI	Prospective cohort. N=49 (28 patella, 17 trochlea, 4 both)	2.8±0.8 cm^2 for patella and 2.8±1.6 cm^2 for trochlea	5 years, with annual evaluations	Significantly more previous/concomitant procedures for patellar lesions (29 TTO *vs.* 0; 32 *vs.* 6 lateral release). Mean IKDC at 5 years: 89.6±12.7 and 69.7±17.6, P<0.005 (trochlea and patella respectively). Kujala at 5 years: (92.4±14.7 *vs.* 81.5±12.7, P=0.012 (trochlea and patella respectively). EQ-VAS at 5 years: 90.0±10.8 *vs.* 81.9±11.7, P=0.027 (trochlea and patella respectively). Tegner at 5 years: 5.9±1.8 and 3.9±1.7, P<0.005 (trochlea and patella respectively)	Women significantly more likely to have patellar lesion. Better results for trochlear lesions *vs* patellar lesions at all f/u intervals. Neither group returned to pre-injury level of sport but both groups improved, with significantly more improvement seen in trochlear lesions. Patella and trochlea lesions should be treated as different entities
Macmull (49); ACI/MACI	Retrospective cohort. N=48; 25 ACI and 23 MACI	4.75 cm^2 (1–10.5)	40.3 months	Statistically significant improvement in subjective pain scoring using VAS and objective functional scores using the Modified Cincinnati Rating System (MCS). Good/excellent results in 40% ACI patients. Good/excellent results in 57% MACI patients. Medial-facet lesions had statistically significant excellent and good results compared with lateral lesions (P=0.029). Medial lesions did better than multi-facet lesions (P=0.007)	Although not significant (P<0.07), MACI tended to have better outcomes than ACI. Given that MACI is technically easier than ACI as well as quicker, recommended to use MACI *vs.* ACI
Nawaz (50); ACI/MACI	Retrospective cohort. N=827 (308 ACI, 519 MACI)	409 mm^2 (range, 64–2,075 mm^2). 51% MFC, 13% LFC, 24% patella, 6% trochlea, 6% multiple	6.2 years (range, 2–12 years)	Significant improvement in VAS, modified Cincinnati, and Stanmore functional scores. LFC grafts lasted the longest—all other sites had significantly increased hazard ratio of failure (except trochlea). Younger patients were significantly (P<0.001) more likely to have longer graft survival than older patients	No significant difference in graft survivorship was found between ACI and MACI. MACI group had significantly better functional scores *vs.* ACI. Overall graft survival of 78% at 5 years and 51% beyond 10 years for both techniques
PJAC					
Tompkins (51)	Retrospective. N=15 knees in 13 patients. No pre-operative/baseline scores available	All patella lesions. Mean defect size: 2.4±1.2 cm^2. Mean packets used: 1.9±0.8. 5 knees with AMZ. 3 with AMZ+MPFL. 2 with MPFL	Mean f/u 28.8±10.2 mo	Mean ICRS cartilage repair assessment score on MRI was 8.0±2.8. Mean defect surface area filled was 89%±19.6%, with all but 3 knees showing >90% fill. Mean IKDC score at f/u: 73.3±17.6. KOOS-pain: 84.2±14.2. KOOS-symptoms and stiffness: 85.0±12.3. KOOS-ADLs: 88.9±12.9. KOOS-sports and rec: 62.0±25.1. KOOS-QOL: 60.8±28.6. Kujala: 79 (range, 55 to 99). VAS: 1.9±1.4 (minimal pain)	PJAC provides viable option for Grade IV chondral lesions in the patella. Tegner score at final follow up [5] shows some decrease in activity level *vs.* prior to surgery [7]. Subgroup analysis showed no significant differences between PF pain patients and PF instability patients except for high Tegner scores for instability patients at f/u (P=0.02). Subgroup analysis showed no difference in outcomes for those with concomitant procedures *vs* those without except for higher post-op VAS scores (2.5±1.4 *vs.* 0.8±0.6, P<0.01)
Grawe (52)	Prospectively collected data. N=45, 42 with concomitant procedure	All patella lesions. Average size 208 mm^2 (range, 4–500 mm^2). Average donor age =49.5 months (range, 3–120 months). Average patient age =26.5 years (range, 13–45 years). Average number of allograft packets used =1.7 (range 1–3)	MRI results obtained at 6, 12, and 24 months	6 months: MRI findings revealed that no patient-, graft-, or donor-specific factors correlated with MR scores, and 82% of the knees demonstrated good to excellent fill. 12 months: MRI findings revealed that T2 relaxation times of deep graft demonstrated negative correlation with patient age (P=0.049) and donor age (P=0.006), the integration zone showed a negative correlation with donor age (P=0.026). 85% with good to moderate fill. 24 months: Patient age demonstrated negative correlation with average T2 relaxation times of the deep and superficial graft (P=0.005; P=0.0029) and positive correlation with the superficial zone of the adjacent cartilage (P=0.001). Donor age showed negative correlation with grayscale score (P=0.004) and T2 relaxation times at deep integration zone (P=0.018)	T2 relaxation times of deep and superficial graft and integration zone improved over time (P<0.001) and between each time point. PJAC graft matures over time and is an acceptable method for treating patella chondral lesions
Wang (53)	Retrospective case series. N=30 lesions in 27 patients. 22 patella, 8 trochlea, 3 bipolar	Mean defect size: 214±123 mm^2. 1 package for 20 lesions. 2 packages for 7	Mean f/u 3.84 years (range, 2.57–5.12 years)	IKDC pre-post: 45.9 *vs.* 71.2, P<0.001. KOS-ADL pre-post: 60.7 *vs.* 78.8, P<0.001. Marx Activity Scale: 7.04 *vs.* 7.17, P=0.97 (not sig). Greater BMI associated with lower KOS-ADLs. Lesion fill exceeding 67% by MRI assessment was noted in 69.2%	Outcomes not affected by location (patella *vs.* trochlea), lesion age, concomitant TTO, age, or hx of prior surgery. PJAC allows for significantly improved pain and function scores. Appearance on post-operative MRI does not impact clinical outcome
Buckwalter (54)	Retrospective review. N=13, 6 with concomitant AMZ	All patella lesions. Average size not reported; smallest 5 mm × 5 mm, largest 25 mm × 28 mm	8.2 months (range, 0.67–32.7 months)	The overall KOOS score improved from a mean of 58.4±15.7 to 69.2±18.6 (P=0.04). Improvement in KOOS subscales of pain, activities of daily living (ADL), symptom and WOMAC function all approached but did not reach statistical significance	PJAC can provide short terms relief for high grade lesions of the patella
Farr (55)	Prospective case series. N=29 lesions in 25 patients	Condyles [18] and trochlea [11]. Mean size: 2.7±0.8 cm^2	2 years. 8 patients had 2nd look scope	IKDC: 45.7 → 73.6. KOOS-pain score: 64.1 → 83.7. KOOS-symptoms score: 64.6 → 81.4. KOOS-activities of daily living score: 73.8 → 91.5. KOOS-sports and recreation score: 44.6 → 68.3, KOOS-quality of life score: 31.8 → 59.9. 8 biopsy samples had Type I and II collagen, with Type II > Type I with good integration	Good functional and pain improvements at 2 years. Sequential radiographic follow-up using MRI showed return to near normal cartilage signal by 2 years. Favorable histology in the repair tissue by 2 years in patients that allowed for repeat arthroscopy
Osteochondral					
Astur (59)	Prospective study for OAT. N=33	All patella lesions. Exclusion criteria: lesions <1 cm^2 or >2.5 cm^2, TT-TG >15 mm, abnormal patella tilt or height	2 years	MRI showed 83% integration at 6 months and 100% integration at 12 months. Significant improvement in all most all subscales of SF-36 at 2 years. Lysholm: 57.27 → 80.76 (P<0.001). Fulkerson: 54.24 → 80.42 (P<0.001). Kujala: 54.76 → 75.18 (P<0.001)	Good option for lesions <2.5 cm^2. Excellent improvement in pain and functionality. Excellent incorporation. 3 complications were all arthrofibrosis, successfully treated with arthroscopic lysis of adhesions
Figueroa (60)	Prospective case series, OAT. N=10. All male	All patella lesions. Lesion size <2.5 cm^2. Average 1.9 plugs used per case	37.3 months (range, 24–70 months)	Lysholm: 73.8±8.36 → 95±4.47 (P<0.05). IKDC: Post-op only—93.6±1.74 [92–96]. 80% of cases with <1 cm edema around plug. All cartilage graded as ICRS IA	OCA is a good surgical alternative for full thickness patellar cartilage lesions treatment in young, male individuals. Good and excellent clinical, functional and imaging results at midterm follow-up
Nho (61)	Case series OAT. N=22	All patella lesions. Mean size: 165.6±127.8 mm^2. Mean plugs: 1.8±1.4. Included maltracking cases with concurrent corrections	28.7 mo (range, 17.7–57.8 mo)	Mean preoperative IKDC score was 47.2±14.0 and improved to 74.4±12.3 (P=0.028). Mean preoperative ADL score was 60.1±16.9 and increased to 84.7±8.3 (P=0.022). Patients without distal realignment had significant improvement in IKDC scores (P=0.009) at most recent follow-up, but not for SF-36 (P=0.066) and ADL (P=0.056). 9 patients with distal realignment had non-significant improvement in scores. MRI: all plugs demonstrated good (67–100%) cartilage fill, 64% with fissures <2 mm at the articular cartilage interface, 71% with complete trabecular incorporation, and 71% with flush plug appearance	OAT in the patella provides good outcomes. Those patients with need for distal realignment may be expected to have poorer results compared to those with isolated OAT procedure
Jamali (65)	Retrospective case series. OCA. N=20 knees in 18 patients	20 patella, 12 trochlea. 15 patients with entire patella resurfaced. Average patella plug size in 3 patients 7.1 cm^2 (range, 1.8–17.8 cm^2). Average trochlea lesion 13.2 cm^2 (range, 2.5–22.5 cm^2)	94 months (range, 24–214 months)	5 failures—defined as need for revision OCA, arthroplasty, or arthrodesis. In the remaining 15, clinical scores increased from a mean of 11.7 points (range, 7–15 points) to 16.3 points (range, 12–18 points), P=0.001. The overall rate of excellent or good results was 60% (12 of 20 patients). Kaplan-Meier analysis revealed that the probability of allograft survival at 10 years with a 95% confidence interval was 67%±25%	Viable salvage option of patellofemoral osteochondral lesions. Results are not as good as condylar OCA results from the same institution
Cameron (66)	Case series OCA. N=29 knees (28 patients)	All trochlear lesions. Average graft size 6.1±3.6 cm^2 (2.3–20.0)	7.0 years (range, 2.1–19.9 years)	5-yr survivorship =100%. 10-yr survivorship =91.7%. Significant improvements in Modified Merle d'Aubigne´-Postel, IKDC, and KS-F scores	Good graft survivorship. Durable results. Good improvement in pain and function. High patient satisfaction
Gracitelli (67)	Case series OCA. N=29 knees (28 patients)	All patella lesions. Average graft size 10.1 cm^2 [4–18]	9.7 years for the 20/28 grafts in situ (range, 1.8–30.1 years)	5-, 10-yr survivorship =78.1%. 15-yr survivorship =55.8%. 8/28 knees (28.6%) failed—4 TKA, 2 PFJA, 1 revision OCA, 1 patellectomy). Scores on the IKDC, modified Merle d'Aubigne´-Postel, and KS-F improved significantly. from the preoperative visit to latest follow-up	77% of knees showed excellent or good results according to the modified Merle d'Aubigne´-Postel score categories. 89% of patients were extremely satisfied or satisfied with the results of the OCA transplantation. Patients who retained their grafts had significant improvement in pain and knee function, although 9 (45%) required further surgeries.
Meric (68)	Case series. N=48 knees in 46 patients	34 tibiofemoral. 14 patellofemoral. Mean allograft size 19.2 cm^2	84 months for grafts that remained in situ	Additional surgery required in 63% of knees. 45.8% failure rate. 88% of the non-failures had G/E results. Among the non-failures, 96% reported improved function, 92% reported reduced pain, 88% were extremely satisfied or satisfied with the procedure, and 92% stated that they would undergo OCA transplantation again under similar circumstances	Survivorship at 5 years was 64.1%. Survivorship at 10 years was 39%. Useful as a salvage procedure for bipolar lesions. High reoperation and failure rates were observed, but patients with surviving allografts showed significant clinical improvement.
Gracitelli (69)	Retrospective matched pair cohort study. N=92 (46 for index OCA, 46 for OCA after MST)	All locations in the knee. Index treatment average size: 8.2±3.6 cm^2. Revision treatment average size: 8.0±3.2 cm^2	Minimum 2 yr f/u; evaluated out to 10 yr	Index survivorship at 10 years: 87.4%. Revision survivorship at 10 years: 86. 87% good/excellent outcomes in both groups. Higher re-op rate in revision group (P=0.04). Sig improvement in pain and function from pre-op to final f/u (P<0.01)	OCA can serve as a good solution for index and revision chondral defects. Despite higher re-operation rate in the revision setting, the overall survivorship of the graft was not adversely affected.
Torga Spak (70)	Retrospective. N=14 (2 patella, 12 bipolar) in 11 patients	Advanced secondary OA. Size not listed	Average 10 years (2.5–17.5)	At final f/u, 8 grafts were in place (4 >10 years and 2 >5 years). Of the grafts that failed prior to final f/u, 3 had lasted >10 years. X-rays of intact allografts showed mild to no degenerative changes. Average knee society scores improved for patients with an intact graft. Knee score improved from an average of 46 to 82 and functional scores improved from an average of 30 to average of 75. Mean Lysholm score improved from 27 points to 80 points	Osteochondral allografts used in PF arthritis can improve knee pain and function. OCAs can also delay the need for arthroplasty
Arthroplasty					
Shubun Stein (72)	Retrospective cohort; N=48 in 39 patients	Average patient age 51.6. Average BMI 26.3 with 28.6% >30 kg/m^2	26 mo [5–57]	Kujala score improved mean of 19.5 pts. Lysholm improved a mean of 28.9 points. IKDC improved an average of 23.5 pts. Pain score went from 6.3 preop to 2.8 post-op. All PROs and pain score improvements were greater than the minimal clinically important differences	Almost 75% of patients returned to their preferred activities. >50% of patients returned at the same or higher activity level compared to preoperatively
Odgaard (73)	Randomized control trial. N=100	Isolated end stage PF arthritis. Looked at area under the curve (AUC) for outcome measures	2 years	AUC for SF-36 bodily pain was 9.2±4.3 for PF *vs.* 6.5±4.5 TK (P=0.008). AUC for SF-36 physical functioning was 6.6±4.8 PF *vs.* 4.2±4.3 TK (P=0.028). AUC for KOOS symptoms was 5.6±4.1 PF *vs.* 2.8±4.5 TK (P=0.006). AUC for Oxford Knee Score was 7.5±2.7 PF *vs.* 5.0±3.6 TK (P=0.001). SF-36 bodily pain improvement at 6 months was 38±24 PF *vs.* 27±23 TK (P=0.041); at 2 years not significant difference. KOOS improvements at 6 months was 24±20 PF *vs.* 7±21 (P<0.001); at 2 years 27±19 *vs.* 17±21 (P=0.023)	Patients undergoing PFA obtain a better overall knee-specific quality of life than patients undergoing TKA throughout the first 2 years after operation for isolated patellofemoral osteoarthritis. At 2 years, only KOOS function differs between patients undergoing PFA and those undergoing TKA, whereas other PRO dimensions do not show a difference between groups. Patients undergoing PFA recovering faster than patients undergoing TKA and the functional outcome being better for patients undergoing PFA up to 9 months. Patients undergoing PFA regain their preoperative ROM, whereas patients undergoing TKA at 2 years have lost 10° of ROM. No differences in complications.

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