Orthopaedic Advances

Cartilage Restoration Techniques for the Patellofemoral Joint

Abstract

Symptomatic osteochondral lesions of the patellofemoral joint are clinically challenging to manage because of the limited healing potential of articular cartilage; the complex morphology of the patellofemoral joint; the heterogeneity of the articular surface between patients; and high stresses across the joint, which can be altered by malalignment, tilt, or maltracking. Indications for surgery include traumatic lesions, osteochondritis dissecans, and high-grade chondromalacia in association with persistent pain despite a course of nonsurgical management. Various techniques have been described for managing symptomatic osteochondral lesions of the patellofemoral joint, including microfracture, osteochondral autograft transplantation, and biologic cell transplantation, including autologous chondrocyte implantation. Salvage techniques (eg, fresh allograft) may provide satisfactory outcomes after a failed attempt at surgical management. Irrespective of the surgical technique used, outcomes are generally worse in the patellofemoral compartment than in the tibiofemoral joint. The concomitant management of associated pathology, including patellar malalignment, is recommended because it has been shown to improve the success of cartilage restoration procedures.

Chondral lesions of the patellofemoral joint are a common entity that is identified in >33% of patients undergoing arthroscopic surgery. After the medial femoral condyle, the patella is the second most common location in the knee for the occurrence of Outerbridge grade III and IV chondral lesions. Etiologies for patellofemoral chondral lesions include acute traumatic injuries, such as dislocation and subluxation, microtrauma, osteochondritis dissecans, and degenerative changes. Multiple factors contribute to the increased challenges of performing patellofemoral cartilage restoration procedures compared with procedures in other areas of the knee. First, patellofemoral joint loads may reach 6.5 times body weight, and chondral injuries that alter force distribution may result in even higher loads. Force distribution can be further altered by abnormal patellar tilt, malalignment, and maltracking, as well as patellar or trochlear dysplasia. Second, the complex morphology of the patellofemoral joint and its heterogeneity between patients complicates efforts to restore the native articular surface contour. Third, the patella contains the thickest cartilage in the body, and femoral autograft has structural properties that differ from those of the adjacent native patellar cartilage. Thus, femoral autograft may not adapt well to patellofemoral joint

Robert H. Brophy, MD
Robert D. Wojahn, MD
Joseph D. Lamplot, MD

From Washington University Orthopedics, Chesterfield, MO (Dr. Brophy) and Washington University Orthopedics, Washington University in St. Louis, St. Louis, MO (Dr. Wojahn and Dr. Lamplot).

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stresses. Finally, whereas most tibiofemoral defects can be managed arthroscopically, it is often necessary to perform an arthrotomy to manage patellofemoral defects. These factors may contribute to the inferior outcomes after cartilage restoration of the patellofemoral joint compared with outcomes after cartilage restoration of the tibiofemoral joint.

Untreated chondral lesions may be a contributing factor in activity-limiting anterior knee pain. The main goal in managing patellar and trochlear chondral injuries is to restore cartilage surface congruity with sufficient biomechanical properties to alleviate symptoms, facilitate the return to previous level of activity, and improve quality of life.

**Indications**

The main indications for cartilage restoration are Outerbridge or International Cartilage Repair Society grade III or IV focal chondral or osteochondral defects of the load-bearing articular surface of the patellofemoral joint in patients with symptomatic knee pain in whom a sufficient trial of nonsurgical treatment has been unsuccessful. General contraindications to cartilage restoration include osteoarthritis of the patellofemoral joint, inflammatory disease, medical contraindications, lower grade lesions, and patient inability to comply with postoperative rehabilitation protocols. Additionally, outcomes may be better after management of unipolar lesions and contained lesions than after management of bipolar lesions and uncontained lesions. In patients with patellofemoral malalignment or maltracking, concomitant procedures, such as lateral lengthening, medial reefing, vastus medialis oblique advancement, medial patellofemoral ligament reconstruction, trochleoplasty, or advancement and/or medialization of the tibial tuberosity, should be performed to address this pathology; however, these topics are beyond the scope of this article.

**Surgical Management**

**Microfracture**

In the microfracture technique, an awl is used to penetrate the subchondral bone to facilitate bleeding, clot formation, and migration of marrow-derived mesenchymal stem cells into the defect, thereby promoting fibrocartilage repair. Microfracture of the patella is associated with unique technical challenges, including a higher degree of difficulty in visualizing and accessing the lesions arthroscopically compared with microfracture of the tibiofemoral joint as well as the need to maintain counterpressure on the anterior aspect of the patella. The articular cartilage lesion is identified, and all loosely attached cartilage surrounding the defect is debrided to the level of subchondral bone to create a perpendicular edge of stable articular cartilage surrounding the defect. Using an appropriately angled awl, the surgeon makes multiple holes perpendicular to the subchondral bone surface throughout the defect. These holes are spaced 3 to 4 mm apart and are 3 to 4 mm deep (Figure 1). After microfracture is complete, the irrigation pump is turned off, and bleeding from the subchondral bone is observed.

Indications for microfracture include full-thickness chondral lesions or unstable cartilage overlying subchondral bone with a postdébridement lesion size $< 4 \text{ cm}^2$; outcomes are less predictable in patients with a postdébridement lesion size $\geq 4 \text{ cm}^2$. Microfracture surgery is contraindicated in patients with uncontained chondral lesions. Although good results have been reported after microfracture in the knee overall, no study has specifically investigated microfracture for the management of patellar and/or trochlear lesions (Table 1). Patient factors associated with improved results include age $< 40$ years, preoperative symptoms for $< 12$ months, and body mass index $< 30 \text{ kg/m}^2$. Postoperative concerns include persistent knee pain and mechanical symptoms, recurrent knee effusions, incomplete defect filling or poor integration with surrounding articular cartilage, and deterioration of functional outcomes.
necessitating alternative restoration or arthroplasty procedures.\textsuperscript{14,15,17} Revision rates of approximately 2.5\% to 6\% at 2 years postoperatively and 9\% to 31\% at 5 years postoperatively have been reported.\textsuperscript{15} Although alternative cartilage restoration techniques may be performed if microfracture fails, outcomes of subsequent procedures may be inferior\textsuperscript{9,14} (Table 1).

**Osteochondral Autograft Transplantation**

In osteochondral autograft transplantation (OAT), healthy, intact hyaline cartilage is harvested from a non-weight-bearing portion of the knee joint and then is used to repair full-thickness chondral defects.\textsuperscript{13} The biomechanical properties of healthy hyaline cartilage are superior to those of microfracture-induced fibrocartilage.\textsuperscript{7}

Chondral lesions are identified arthroscopically, then debrided in the same manner as previously discussed for microfracture, after which the lesions are measured. Depending on their location, trochlear lesions may be managed using an all-arthroscopic technique. Patellar lesions, however, must be managed via arthrotomy. The harvest is performed, donor plugs may be harvested from the non-weight-bearing periphery of the femoral condyles. Less commonly, donor plugs are harvested from the intercondylar notch using an all-arthroscopic approach.\textsuperscript{4,6,7} The harvester is positioned perpendicular to the chondral surface, impacted to a depth of approximately 10 mm, and then carefully removed with the donor plug intact. The recipient site is prepared to accept an appropriately sized osteochondral plug by either drilling (in the case of the patella) or impaction of a corresponding recipient core harvester. The use of powered drills may facilitate the creation of more perpendicular drill tunnels, which is critically important to recipient site preparation. The graft is inserted into the recipient socket and gently impacted to match the height of the surrounding cartilage (Figure 2). The graft should not be left proud because it is unlikely to settle over time, and incongruity of the repaired recipient site can permanently alter joint biomechanics and accelerate graft failure.\textsuperscript{6,13} The use of multiple smaller grafts may improve contouring at the recipient site but comes at the expense of decreased coverage of the repair area.\textsuperscript{6,7,13} Plug diameter varies depending on the size of the defect.

<table>
<thead>
<tr>
<th>Study</th>
<th>No. Treated (Anatomic Area)</th>
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<tr>
<td>Gille et al\textsuperscript{14,a}</td>
<td>19 of 57 patients (15 patellae, 4 trochleas)</td>
<td>Inclusion: Outerbridge grade III or IV chondral defects in the knee. Exclusion: Rheumatic disease, total meniscectomy, revision surgery.</td>
<td>24 mo (not available)</td>
<td>3.4\textsuperscript{b}</td>
<td>Patellar realignment (3.5%), osteotomies (5.3%), partial meniscectomy (10.5%), anterior cruciate ligament reconstruction (1.8%).</td>
<td>Improvement in mean outcomes scores from preop to 2-yr follow-up: visual analog scale, 7.0 to 2.0 ($P &lt; 0.001$); Lysholm, 50.1 to 85.2 ($P &lt; 0.001$).\textsuperscript{15} No failures occurred. Revisions were excluded from study. Mean Lysholm score of 80.8 at last follow-up in 11 studies, mean Tegner score of 4.8 at last follow-up in 9 studies, and improved function scores reported in all studies. Revision rates of 2.5%–6% at 2-yr follow-up and 9%–31% at 5-yr follow-up. Revisions performed 6–38 mo postoperatively.</td>
</tr>
<tr>
<td>Milhoefer et al\textsuperscript{15,c}</td>
<td>3,122 knees in 28 studies\textsuperscript{a}</td>
<td>Inclusion: International Cartilage Repair Society grade III or IV chondral or osteochondral defects of the knee. Exclusion: Follow-up rate &lt;70%; knee osteonecrosis.</td>
<td>12 mo (41 mo)</td>
<td>3.0</td>
<td>Meniscal surgery (32%), ligament reconstruction (21%), high tibial osteotomy (11%).</td>
<td>Mean Lysholm score of 59 to 89 ($P &lt; 0.05$); Tegner, 3 to 6 ($P &lt; 0.05$).\textsuperscript{b} Results were good to excellent at final follow-up based on SF-36 and WOMAC scores. 5.1% failure rate, with 1 patient undergoing Fulkerson osteotomy and 1 undergoing repeat microfracture.\textsuperscript{c}</td>
</tr>
<tr>
<td>Steadman et al\textsuperscript{14,a}</td>
<td>39 of 71 knees (10 patellae, 24 trochleas, 5 bipolar)</td>
<td>Inclusion: Isolated traumatic full-thickness chondral defects, age ≤45 yr. Exclusion: No ligament or meniscal pathology, tibiofemoral joint malalignment, chronic degenerative arthritis.</td>
<td>84 mo (136 mo)</td>
<td>2.77\textsuperscript{c}</td>
<td>None</td>
<td>Improvement in mean scores from preop to final follow-up: Lysholm, 59 to 89 ($P &lt; 0.05$); Tegner, 3 to 6 ($P &lt; 0.05$).\textsuperscript{b} Results were good to excellent at final follow-up based on SF-36 and WOMAC scores. 5.1% failure rate, with 1 patient undergoing Fulkerson osteotomy and 1 undergoing repeat microfracture.\textsuperscript{c}</td>
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preop = preoperatively, SF-36 = Medical Outcomes Study 36-item Short Form, WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index

\textsuperscript{a} Retrospective case series

\textsuperscript{b} All compartments of knee included in data

\textsuperscript{c} Systematic review
but typically ranges in size from 5 to 10 mm; up to 16 plugs can be used.\textsuperscript{4,6,7,13,18-20}

The graft harvest should be limited to approximately 3 to 4 cm\textsuperscript{2} in size. Although up to 8 to 9 cm\textsuperscript{2} of graft can be harvested, donor sites of this size place the patient at increased risk for donor site morbidity.\textsuperscript{7} Typically, donor sites fill in with fibrocartilage; however, if >5 cm\textsuperscript{2} of graft is harvested and the harvest site is neither grafted nor filled with biosynthetic plugs, the patient is at risk for failure of the donor surface to reconstitute.\textsuperscript{13} The authors of one article reported giant cell inflammatory reactions in two patients after implantation of biosynthetic plugs.\textsuperscript{21} Both patients underwent revision surgery. In a different study, donor site symptoms resolved within 6 weeks postoperatively in 95\% of patients who underwent OAT from the non-weight-bearing femoral condyle margin to manage chondral defects outside the knee.\textsuperscript{7} The preference of the senior author (R.H.B.) is to harvest graft measuring \(\leq 2.5\) to 3 cm\textsuperscript{2} in total area to minimize donor site morbidity and avoid the routine use of biosynthetic graft to fill donor holes.

Specific indications for OAT include relatively large osteochondral lesions of \(> 1\) cm\textsuperscript{2} in size but \(< 4\) to 8 cm\textsuperscript{2}. Lesions \(< 2\) cm\textsuperscript{2} are associated with the best outcomes.\textsuperscript{22} Patients who are treated with a single plug,\textsuperscript{4} patients who do not require concomitant realignment procedures,\textsuperscript{6} and patients who have isolated traumatic chondral lesions are among those with improved outcomes.\textsuperscript{13} Inferior outcomes may occur in patients who have both medial and lateral patellar facet lesions;\textsuperscript{4} who are aged \(\geq 50\) years;\textsuperscript{7} who have larger surface area lesions;\textsuperscript{4,6,13,22} and who require at least six grafts, which places them at increased risk for donor site morbidity.\textsuperscript{13} Complication and failure rates, which are relatively low in comparison with other cartilage restoration techniques, include stiffness requiring manipulation under anesthesia (3\% to 9\%) and graft failure (zero to 8\%);\textsuperscript{4,6,18,20} (Table 2).

### Autologous Chondrocyte Implantation

Autologous chondrocyte implantation (ACI) is the most well-established and widely used biologic cell transplantation technique. ACI is a two-stage procedure. In the first stage, 100 to 300 mg of healthy articular cartilage is harvested from the non-weight-bearing portion of the femoral condyles or intercondylar notch, and the cartilage is sent for culture and expansion of donor chondrocytes. In the second stage, the expanded chondrocytes are re-implanted within the prepared defect site during a second procedure 3 to 8 weeks later.\textsuperscript{1,5} The first-generation technique consisted of injection of cultured chondrocytes into the defect beneath a collagen membrane or periosteal patch.\textsuperscript{3,12,18} Although this method is effective, it necessitates water-tight adhesion of the patch to surrounding cartilage and may be complicated by periosteal hypertrophy.\textsuperscript{3} The second-generation technique, which is also referred to as matrix-induced autologous chondrocyte implantation or matrix-induced autologous chondrocyte transplantation, consists of seeding cultured chondrocytes onto three-dimensional scaffolds before implantation.\textsuperscript{1,12} The third-generation technique, which is similar to the second-generation technique, consists of implantation of cultured chondrocytes within threedimensional chondroinductive or chondroconductive matrices.\textsuperscript{1,10,12}

Outcomes are better in patients who have isolated trochlear defects than in those who have patellar defects.\textsuperscript{1} Patients treated with concomitant proximal or distal realignment surgery tend to have good outcomes, and patients with unipolar lesions have better outcomes than those with bipolar lesions.\textsuperscript{3,5,10,12} Revision rates are relatively high, ranging from zero to 72\%; complications include arthrofibrosis (8\% to 18\%) and periosteal hypertrophy or extrusion (6\% to 32\%);\textsuperscript{3,5,9,10,16} (Table 3). In a systematic review, Trinh et al.\textsuperscript{10} reported an overall revision rate of 16\% and an overall complication rate of 15\% for all patients undergoing isolated patellar or trochlear ACI.

### Other Techniques and Salvage Options

Osteochondral allograft has been used as a salvage procedure for chondral lesions that are too large to be managed using other cartilage restoration procedures in patients who are poor candidates for arthroplasty procedures.\textsuperscript{2,13,16} The technique for osteochondral allograft is similar to OAT, albeit with larger recipient sites into which matching plugs prepared from cadaver tissue are placed. Although concerns of
<table>
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<tr>
<th>Study</th>
<th>Number (Anatomic Area)</th>
<th>Criteria</th>
<th>Minimum Follow-up in Months</th>
<th>Mean Lesion Size (cm²)</th>
<th>Concomitant Procedures for Associated Pathology</th>
<th>Outcomes</th>
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</thead>
<tbody>
<tr>
<td>Astur et al.a,b</td>
<td>33 defects (patella)</td>
<td>Inclusion: ICURS grade III or IV patellar lesion, lesion size of 1–2.5 cm², age &lt;60 yr Exclusion: Patellar tilt abnormality, patella alta or baja, TTTG &gt;15 mm, ACL or meniscal pathology, infection, systemic inflammatory disease</td>
<td>24 (median: 30)</td>
<td>NR</td>
<td>None</td>
<td>Significant improvement in mean scores from preop to postop (P &lt; 0.05): Lysholm, 57 to 81; Fulkerston, 54 to 80; Kujala, 55 to 75; all SF-36 subscales. MRI demonstrated 100% osseous integration at 1-yr follow-up, 9% of patients required arthroscopic LOA.</td>
</tr>
<tr>
<td>Bentley et al.a,b</td>
<td>7 of 100 patients (5 patellae, 2 trochleas)</td>
<td>Inclusion: Symptomatic knee articular cartilage lesions Exclusion: Ligamentous injury, cartilage lesions in other compartments</td>
<td>12 (mean: 19)</td>
<td>4.66d</td>
<td>None</td>
<td>60% rate of good modified Cincinnati results for patellar lesions (P = 0.078 compared with ACI); too few trochlea lesions for such analysis. Of the cohort of 100 patients treated with either ACI or OAT, 3 required MUA and 1 required arthroscopic LOA.</td>
</tr>
<tr>
<td>Figueroa et al.a,b</td>
<td>10 defects (patella)</td>
<td>Inclusion: Symptomatic patellar cartilage lesion, &lt;2.5 cm² in diameter, age &lt;40 yr Exclusion: Ligamentous injury, cartilage lesions in other compartments</td>
<td>24 (mean: 37)</td>
<td>1.2</td>
<td>Medial patellofemoral ligament reconstruction (15%), chondral fragment fixation (15%), microfracture (15%), and medial retinacular repair (15%) were the top four concomitant procedures performed</td>
<td>Mean Lysholm score improved from 74 preop to 95 postop (P &lt; 0.05), with 100% of scores rated good or excellent. Mean postop IKDC, 94. All patellae demonstrated ICURS grade IA on postoperative MRI. No revisions or failures occurred.</td>
</tr>
<tr>
<td>Hangody and Füles.c</td>
<td>118 of 831 patients (patellae and/or trochleas)</td>
<td>Inclusion: Isolated Outerbridge grade III or IV cartilage lesion or osteochondral defect</td>
<td>NR</td>
<td>NR</td>
<td>85% of the 831 patients treated underwent concomitant procedures, including ACLR, realignment osteotomies, meniscal surgery, and patellofemoral realignment</td>
<td>79% of patients achieved good to excellent clinical scores. Deep infection requiring débridement developed in 0.5% of the 831 patients treated, and hemarthrosis requiring débridement developed in 1% of the full patient cohort.</td>
</tr>
<tr>
<td>Jakob et al.c,d</td>
<td>16 of 52 patients (patellae and/or trochleas)</td>
<td>Inclusion: Symptomatic ICURS grade III or IV cartilage lesion without osteoarthritis: OCD (6%), maltracking with dislocation (31%), patellofemoral arthrosis (63%) Exclusion: Patellar tilt abnormality, patella alta or baja, TTTG &gt;15 mm, ACL or meniscal pathology, infection, systemic inflammatory disease</td>
<td>24 (mean: 37)</td>
<td>4.9c</td>
<td>TT advancement (25%), TT medialization (10%), lateral release (13%), trochleoplasty (6%), high tibial osteotomy (13%), ACLR (10%), partial meniscectomy (6%)c</td>
<td>92% of patients had achieved increased knee function and activity by final follow-up (range, 24–56 mo). 8% of patients experienced graft failure and underwent revision.c</td>
</tr>
<tr>
<td>Karataglis et al.c,d</td>
<td>11 of 37 knees (4 patellae, 7 trochleas)</td>
<td>Inclusion: Knee articular cartilage injury resulting from OCD, osteonecrosis, lateral patellar maltracking, or trauma</td>
<td>18 (mean: 37)</td>
<td>2.73c</td>
<td>ACLR (11%), lateral meniscal repair (3%), lateral release or TTO (19%)c</td>
<td>Mean Tegner Activity Scale score of 3.76 and mean Knee Outcome Survey ADL Scale score of 72.3 at final follow-up based on the entire cohort of 36 patients. 24% of patients underwent repeat arthroscopy for pain, swelling, or mechanical symptoms.c</td>
</tr>
<tr>
<td>Nho et al.c,d</td>
<td>22 defects (patella)</td>
<td>Inclusion: Isolated symptomatic Outerbridge grade III or IV patellar lesion Exclusion: Additional cartilage lesions, concomitant correction of varus or valgus malalignment, or ligament reconstruction</td>
<td>18 (mean: 29)</td>
<td>1.66</td>
<td>Lateral release (59%), distal realignment (41%), proximal realignment (14%)</td>
<td>Improvement in mean outcomes score from preop to postop: IKDC, 47.2 to 74.4 (P = 0.059); Knee Outcome Survey ADL, 60.1 to 84.7 (P = 0.023); SF-36, 64.0 to 79.4 (P = 0.059). All plugs demonstrated good (67–100%) cartilage fill on MRI. 1 patient required arthroscopic débridement and repeat lateral release.</td>
</tr>
</tbody>
</table>

ACI = autologous chondrocyte implantation, ACL = anterior cruciate ligament, ACLR = anterior cruciate ligament reconstruction, ADL = activities of daily living, ICURS = International Cartilage Repair Society, IKDC = International Knee Documentation Committee, LOA = lysis of adhesions, MUA = manipulation under anesthesia, NR = not reported, OAT = osteochondral autograft transplantation, OCD = osteochondritis dissecans, postop = postoperatively, preop = preoperatively, SF-36 = Medical Outcomes Study 36-Item Short Form, TT = tibial tuberosity, TTO = tibial tubercle osteotomy, TTTG = tibial tubercle and trochlear groove distance

a Prospective case series
b Randomized controlled trial
c All compartments of knee included in data
d Retrospective case series
### Table 3

<table>
<thead>
<tr>
<th>Study</th>
<th>No. Treated (Anatomic Area)</th>
<th>Criteria</th>
<th>Minimum Follow-up (mean)</th>
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<tr>
<td>Bentley et al</td>
<td>21 of 100 patients (20 patellae, 1 trochlea)</td>
<td>Inclusion: Symptomatic lesions of the articular cartilage of the knee</td>
<td>12 mo (19 mo)</td>
<td>4.66⁶</td>
<td>None</td>
<td>Excellent or good modified Cincinnati score achieved in 85% of patellar lesions after ACI, compared with 60% after mosaicplasty (P = 0.007). Too few trochlear lesions for statistical analysis. Of the cohort of 100 patients treated with either ACI or OAT, 3 required MUA and 1 required arthroscopic LOA.</td>
</tr>
<tr>
<td>Ebert et al</td>
<td>47 patients (24 patellae, 23 trochleas)</td>
<td>Inclusion: Isolated ICRS grade III or IV patellofemoral chondral defect; age range, 18–65 yr Exclusion: Body mass index &gt;35 kg/m² ligamentous instability, varus/valgus abnormalities, inflammatory arthritis</td>
<td>24 mo (NR)</td>
<td>3.3</td>
<td>TTO (40%)</td>
<td>All KOOS values had improved by 2 yr postop (P &lt; 0.001); SF-36 physical and mental component scores improved by 1 and 2 yr postop (P = 0.002); and VAS scores showed improvement at 3 mo, 1 yr, and 2 yr postop (P &lt; 0.001). MRI demonstrated complete graft infill in 40.4% of patients at 2-yr follow-up. At 2-yr follow-up, 3 patients demonstrated asymptomatic graft hypertrophy, and 2 patients demonstrated graft failure.</td>
</tr>
<tr>
<td>Farr et al</td>
<td>39 knees in 38 patients (14 patellae, 18 trochleas, 7 bipolar)</td>
<td>Inclusion: ICRS grade III or IV patellar and/or trochlear lesion treated with ACI Exclusion: Other concurrent cartilage repair procedures in knee</td>
<td>6 mo (median: 37 mo)</td>
<td>5.4 (patella), 4.3 (trochlea), 8.8 (bipolar)</td>
<td>TT anteromedialization (74%), lateral release (6%), MPFL reconstruction (3%), other (13%)</td>
<td>Improvement in median scores from preop to final follow-up: modified Cincinnati, 4 to 6 (P = 0.0001); Lysholm, 58 to 86 (P &lt; 0.0001); restining VAS pain, 2 to 0 (P = 0.007); maximum VAS pain, 8 to 4 (P &lt; 0.0001). 66% of patients underwent revision, 37% for painful osteotomy hardware, 18% for major mechanical symptoms, 13% for arthrofibrosis, and 3% for acute knee sepsis. Some patients underwent more than one subsequent operation.</td>
</tr>
<tr>
<td>Filardo et al</td>
<td>49 patients (28 patellae, 17 trochleas, 4 bipolar)</td>
<td>Inclusion: Symptomatic ICRS grade III or IV patellofemoral lesions Exclusion: Patellofemoral malalignment, tibiofemoral malalignment, diffuse osteoarthritis, “general medical conditions”</td>
<td>60 mo (NR)</td>
<td>3.0</td>
<td>Lateral release (27%), realignment procedures (12%), meniscectomies (14%), ACLR (4%), other (6%)</td>
<td>Improvement in mean outcome scores from preop to 5-yr follow-up: IKDC, 36.1 to 76.7 (P &lt; 0.0005); EuroQol visual analogue scale, 57.3 to 84.4 (P &lt; 0.008); Kujala, 48.7 to 85.7 (P &lt; 0.005); Tegner, 1.9 to 4.7 (P &lt; 0.0005). Outcomes after repair of trochlear lesions were better than repair of patellar lesions for all measures. No revisions were performed, but 6% of patients experienced no improvement in symptoms.</td>
</tr>
<tr>
<td>Gillogly and Arnold</td>
<td>25 knees in 23 patients (patella)</td>
<td>Inclusion: Failed primary treatment of isolated Outerbridge grade IV patellar chondral defects managed with ACI and TTO</td>
<td>61 mo (91 mo)</td>
<td>6.4</td>
<td>All underwent TT anteromedialization, and a few underwent trochleoplasty</td>
<td>Improvement in mean outcome scores from preop to final follow-up: IKDC, 43 to 76 (P &lt; 0.0001); Lysholm, 40 to 79 (P &lt; 0.0001); modified Cincinnati, 3.0 to 7.6 (P &lt; 0.0001); SF-12 physical, 41 to 48 (P = 0.002); SF-12 mental, 48 to 61 (P = 0.0001). 40% of knees required revision, 32% underwent debridement for graft hypertrophy, and 4% experienced treatment failure.</td>
</tr>
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ACI = autologous chondrocyte implantation, ACLR = anterior cruciate ligament reconstruction, Cincinnati = Cincinnati Knee Rating System, HTO = high tibial osteotomy, ICRS = International Knee Documentation Committee, KOOS = Knee Outcome and Osteoarthritis Outcome Score, LOA = lysis of adhesions, MPFL = medial patellofemoral ligament, MUA = manipulation under anesthesia, NR = not reported, OAT = osteochondral autograft transplantation, postop = postoperatively, preop = preoperatively, SF-12 = Medical Outcomes Study 12-Item Short Form, SF-36 = Medical Outcomes Study 36-Item Short Form, TT = tibial tuberosity, TTO = tibial tubercle osteotomy, VAS = visual analog scale, WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index

a Randomized controlled trial
b All compartments of knee included in data
c Prospective case series
d Prospective cohort
e Retrospective case series
f Systematic review
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<td>Minas and Bryant6,7</td>
<td>45 patients (10 patellae, 11 trochleas, 24 bipolar)</td>
<td>Inclusion: ACh involving the patella and/or trochlea, &gt;50% joint space remaining, focal chondral defects only</td>
<td>24 mo (46 mo)</td>
<td>4.9 (patella), 5.2 (trochlea)</td>
<td>TTO (62%), HTO (18%)</td>
<td>Mean SF-36 (mental and physical) scores improved (P &lt; 0.0016), as did Knee Society Score knee and function scores (P &lt; 0.002). Mean WOMAC score improved from 37.1 preop to 24.4 postop (P &lt; 0.0001), and mean modified Cincinnati scores improved from 3.84 preop to 5.76 postop (P &lt; 0.001). 18% failure rate.</td>
</tr>
<tr>
<td>Nawaz et al8,9</td>
<td>250 of 827 patients (200 patellae, 50 trochleas)</td>
<td>Inclusion: Skeletally mature patients with symptomatic osteochondral patellofemoral defect Exclusion: Tibiofemoral or patellar malalignment, clinical instability, previous ACh, or inflammatory arthritis</td>
<td>24 mo (74 mo)</td>
<td>4.099</td>
<td>None</td>
<td>Outcomes data are based on the full cohort of 1,000 patients. Improvement in mean outcome scores from preop to final follow-up: modified Cincinnati, 46.9 to 66.7 (P = 0.001); Stanmore, 2.78 to 1.70 (P &lt; 0.001); VAS, 5.95 to 3.56 (P &lt; 0.001). Survival rate of 78.2% at 5 yr and 50.7% at 10 yr.</td>
</tr>
<tr>
<td>Noyes and Barber-Westin10</td>
<td>613 knees in 18 studies (302 patellae, 106 trochleas, 118 both, 34 femoral condyles, 53 variety of combinations of locations)</td>
<td>Inclusion: Patellar lesions ≤4 cm², mean age &lt;50 yr, ≥2-yr follow-up Exclusion: Nonsurgical treatment or débridement</td>
<td>36 mo (74 mo)</td>
<td>5.1</td>
<td>TTO, MPFL reconstruction, HTO, ACLR, or lateral release (41%)</td>
<td>8% overall failure rate. 8%-18% rate of arthrofibrosis. 5%-72% revision rate.</td>
</tr>
<tr>
<td>Trinh et al1,11</td>
<td>366 patients (285 patellae, 81 trochleas)</td>
<td>Inclusion: Primary ACh of Outerbridge grade III or IV patellofemoral chondral defects, results reported separately with and without distal realignment procedures, ≥2-yr follow-up</td>
<td>24 mo (50 mo)</td>
<td>NR (range, 2.2–6.8 mo)</td>
<td>23% of patients underwent either previous or concomitant distal realignment procedures</td>
<td>Significant improvement in modified Cincinnati, SF-36, Lyshom, Tegner, and IKDC scores in patients who underwent ACh plus realignment compared with ACh alone (P &lt; 0.05). 16.3% revision rate after ACh alone compared with 32.1% after ACh plus realignment (P = 0.07 after excluding hardware removal). 15.2% complication rate after ACh alone, compared with 19% after ACh plus realignment (P = 0.41). 74%–94% of complications resulting from graft hypertrophy or erosion.</td>
</tr>
<tr>
<td>Vassiliadis et al12</td>
<td>92 patients (39 patellae, 8 trochleas, 45 bipolar)</td>
<td>Inclusion: Symptomatic full-thickness chondral lesion involving the patella and/or the trochlea</td>
<td>NR (151 mo)</td>
<td>5.5</td>
<td>Extensor mechanism reconstruction and proximal trochleoplasty (23%), extensor mechanism reconstruction only (9%), HTO (4%), other (2%)</td>
<td>Median Tegner score improved from 2 preop to 3 at final follow-up (P = 0.02). Median Lyshom score improved from 61 preop to 70 at final follow-up, 5.4% failure rate. 29% of patients experienced perosteal hypertrophy and 8% experienced arthrofibrosis requiring manipulation.</td>
</tr>
</tbody>
</table>

ACh = autologous chondrocyte implantation, ACLR = anterior cruciate ligament reconstruction, Cincinnati = Cincinnati Knee Rating System, HTO = high tibial osteotomy, ICRS = International Cartilage Repair Society, IKDC = International Knee Documentation Committee, KOOS = Knee Injury and Osteoarthritis Outcome Score, LOA = lysis of adhesions, MPFL = medial patellofemoral ligament, MUA = manipulation under anesthesia, NR = not reported, OAT = osteochondral autograft transplantation, postop = postoperatively, preop = preoperatively, SF-12 = Medical Outcomes Study 12-Item Short Form, SF-36 = Medical Outcomes Study 36-Item Short Form, TT = tibial tuberosity, TTO = tibial tubercle osteotomy, VAS = visual analog scale, WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index

5 Randomized controlled trial
6 All compartments of knee included in data
8 Prospective case series
9 Prospective cohort
10 Retrospective case series

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Gracitelli et al\textsuperscript{24} reported a 78.1\% graft survivorship rate at 5- and 10-year follow-up, a 55.8\% graft survivorship rate at 15-year follow-up, a 61\% revision rate, and an 89\% overall patient satisfaction rate.

Additional salvage options include patellofemoral arthroplasty and total knee arthroplasty.\textsuperscript{2,5,16} In a systematic review of large patellofemoral cartilage lesions measuring $\geq 4 \text{ cm}^2$ in patients aged $\leq 50$ years, Noyes and Barber-Westin\textsuperscript{16} reported a failure rate of zero to 24\% after patellofemoral arthroplasty and a mean failure rate of 32\% after osteochondral allograft, with no benefit achieved in an average of 22\% and 53\% of patients, respectively.

A relatively new technique with limited data in the patellofemoral joint involves the use of particulated juvenile cartilage allograft (DeNovo NT Natural Tissue Graft; Zimmer Biomet), which may have indications similar to ACI and a theoretical advantage over ACI because, as allograft, there is no limit to the amount of implantable material available for use in a single-stage procedure.\textsuperscript{2} Additional studies are needed to better determine indications and assess outcomes after these procedures.

**Postoperative Rehabilitation**

Postoperative rehabilitation is similar irrespective of the restoration procedure. Continuous passive motion and cryotherapy are begun immediately postoperatively. Weight bearing is allowed within 1 to 2 weeks postoperatively with a hinged knee brace locked in extension for 4 to 8 weeks postoperatively to reduce shear on the repair site with ambulation.\textsuperscript{17}

**Outcomes**

Significant improvement in mean Lysholm score at 2-year\textsuperscript{14} and 7-year\textsuperscript{17} follow-up has been reported for microfracture in all compartments of the knee ($P < 0.001$ and $P < 0.05\), respectively). These studies included patients who underwent patellar and/or trochlear microfracture, but results were not specified by lesion location. No study to date has provided outcome data specifically for patellar or trochlear lesions after microfracture. MRI evaluation after patellar OAT demonstrated 67\% to 100\% cartilage repair fill at a mean follow-up of 28.7 months in one study\textsuperscript{6} and 100\% osseous integration at 1-year follow-up in a different study.\textsuperscript{4} Ebert et al\textsuperscript{12} reported MRI findings of 40.4\% complete graft infill in patients who had undergone ACI. They anecdotally noted that trochlear lesions are more forgiving than patellar lesions but demonstrated no clinical or radiologic differences in outcomes. Using a first-generation ACI technique, Farr\textsuperscript{8} also reported that outcomes were similar for the patella and the trochlea. Conversely, Filardo et al\textsuperscript{1} demonstrated improved outcomes, and Nawaz et al\textsuperscript{9} demonstrated improved graft survival after ACI to manage trochlear lesions compared with patellar lesions. Recent studies using fresh allograft also demonstrated improved outcomes for isolated trochlear lesions compared with patellar lesions.\textsuperscript{23,24} It is unclear why treatment outcomes may be better for trochlear lesions than for patellar lesions, but the difference may in part be the result of better vascularity of the trochlea or the increased difficulty in accessing patellar lesions. To our knowledge, no data exist comparing the outcomes of trochlear and patellar lesions after microfracture or OAT. Because the data suggest better outcomes after management of trochlear lesions than patellar lesions, it may be better to consider them as separate entities in future studies.\textsuperscript{1,5,9,11,23,24}

**Summary**

Several methods have been described for the surgical management of patellofemoral chondral lesions, and the heterogeneity of outcome measures used makes comparison of techniques somewhat difficult. Regardless of the method used, patellar malalignment and/or maltracking should be managed before or during the surgeon's cartilage restoration procedure of choice to optimize outcomes and reduce the likelihood of treatment failure and revision. Microfracture is a good first-line cartilage restoration technique for the treatment of small, contained chondral lesions, and even if the treatment fails, the patient may be a candidate for an alternative cartilage restorative procedure. OAT is associated with lower comparative revision rates, complication rates, and cost, as well as equivalent or better patient outcome scores compared with osteochondral allograft; thus, OAT is a good option for managing larger lesions and patients in whom microfracture has been unsuccessful. ACI is an option for large lesions ($> 4 \text{ cm}^2$). Osteochondral allograft is a good option for managing defects $> 2$ to 4 cm\textsuperscript{3} or after failed OAT or ACI. Further studies specific to management of the patella and trochlea are needed to better understand the optimal indications for and outcomes of patellofemoral cartilage restoration surgery.

**References**

*Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, reference 18 is a level I study. References 1 and 5 are level II studies. References 3, 4, 6-17, and 19-24 are level IV studies. Reference 2 is level V expert opinion. References printed in bold type are those published within the past 5 years.*


