Patellofemoral (PF) cartilage defects are common. They may result from instability, incongruity between the patella and trochlea, repetitive overload (microtrauma), or direct impact (macrotrauma). If exhaustive conservative management fails to resolve symptoms of disabling anterior knee pain with activities of daily living, surgical treatment may be considered. There are 3 main indications for osteochondral allograft transplantation: cartilage defects that are associated with extensive abnormalities of the subchondral bone or frank bone loss that are expected to compromise surface procedures such as autologous chondrocyte implantation; cartilage defects that are associated with severe trochlear dysplasia; and PF osteoarthritis in young patients who are not candidates for arthroplasty. Osteochondral allograft transplantation is performed using 1 of the 2 following techniques, depending on the location and extent of cartilage damage being addressed. The dowel or press-fit technique utilizes a cylindrical reamer and coring reamer system to fashion a dowel and recipient site with a diameter ranging from 15-35 mm. The shell technique is an alternative, which addresses very large defects in which the chondral defect area is removed along with bone with a saw using the same plane (as for prosthetic resurfacing total knee arthroplasty or PF arthroplasty). Careful assessment of PF kinematics and anatomy (or pathokinematics and pathoantatomy) are the key to optimizing success. In light of these factors, associated procedures (such as tibial tuberosity osteotomies, medial PF ligament reconstruction, or lateral retinacular lengthening) are very common in PF cartilage repair, especially with bipolar grafts. With attention to detail and technique, successful outcomes may be achieved in many patients.

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KEYWORDS osteochondral allograft, patella, trochlea, patellofemoral

Background

Patellofemoral (PF) cartilage defects are common. The PF compartment and the medial femoral condyle are the most frequently affected locations in the knee joint. Cartilage defects in the PF joint are multifactorial. They may be a result of instability, incongruity between the patella and trochlea, repetitive overload (microtrauma), or direct impact (macrotrauma). Totally 90% of patellar dislocations result in some damage to the articular cartilage, ranging from simple fissures to large osteochondral fractures. If exhaustive conservative management fails to resolve symptoms of disabling anterior knee pain with activities of daily living, surgical treatment may be considered.

Indications

There are 3 main indications: cartilage defects that are associated with extensive abnormalities of the subchondral bone that are expected to compromise surface procedures such as autologous chondrocyte implantation; cartilage defects that are associated with severe trochlear dysplasia; and PF osteoarthritis in young patients who are not candidates for arthroplasty.
Surgical Technique

Osteochondral allograft transplantation is performed by 1 of 2 techniques, depending on the location and extent of cartilage damage being addressed.\(^\text{14}\) The dowel or press-fit technique utilizes a cylindrical reamer and coring reamer (circular saw) system to fashion a dowel and recipient site with a diameter ranging from 15-35 mm. The dowel is typically slightly oversized to allow press-fit, implant-free fixation in the recipient site. Generally, proprietary instrumentation for graft preparation is provided free of charge by the respective tissue bank. Smaller dowels are used predominantly for defects that do not cross the midline, that is, those located in their entirety on the medial or lateral aspect of the patella or trochlea and are thus somewhat independent of morphology (eg, Wiberg type of patella or trochlear groove angle). Central defects can be treated as well, but are technically more challenging to match perfectly owing to the complex geometry of the trochlea groove and median ridge (Fig. 1). DeBerardino (personal communication) has described using a “mega-OAT (osteo-chondral allograft transfer)” technique that resurfaces nearly the entire patella with 1 very large plug (Fig. 2). Taken a step further, the shell technique is an alternative to address the very large defects. In this technique, the chondral defect area is removed along with bone with a saw using the same plane as for patellar resurfacing (total knee arthroplasty or PF arthroplasty), leaving a uniform thickness of 12-15 mm. Host patellar bone thinner than 12 mm may increase the risk of fracture and thicker remaining host bone may significantly increase the final composite patellar thickness, which could increase PF contact forces. A size-matched graft is created using a similar cut using a free-hand technique (a commercial “lobster claw” patella clamp may be useful to stabilize the patellar graft in some cases). The graft is secured with antegrade or retrograde metal or resorbable screws (preferable to pins). Careful attention should be paid to the countersunk hardware to assure that it will not become proud in the future, thus having the potential to abrade the opposing joint surface. In addition to addressing any size and shape of cartilage defect, the shell technique can address also trochlear dysplasia, where chondrosis would preclude trochleoplasty. The dysplastic native trochlea is replaced with a normally shaped graft. If the patella is also involved with extensive chondrosis or if the native patella shape would lead to suboptimal contact area due to marked incongruency of the PF articulation, bipolar allograft resurfacing may be considered. In Figure 3, cartilage repair results are shown for the shell technique.

Associated procedures are very common in PF cartilage repair. Careful assessment of PF kinematics and anatomy (or pathokinematics and pathoanatomy) is the key to optimizing the success of these procedures. Femoral and tibial derotations, realignment of severe valgus deformity, lateral retinacular lengthening, quadriceps muscle derotation or selective lengthening of the quadriceps tendon, tibial tuberosity transfer, and medial patellofemoral ligament reconstruction should all be considered to optimize

Figure 1 (A) Cartilage damage of the patella preoperatively. (B) Mega-OAT pumapatellar socket created with guide pin and reamer. Base drilled to promote bony healing. (C) Cartilage repair with mega-OAT plug. (Photographs courtesy of Dr. Tom DeBeradino.)
PF forces per unit contact area, tracking, stability, and thus function.

**Dowel and Mega-OAT Technique**

A size-matched fresh-stored (<30 days after retrieval) osteochondral allograft is ordered. Matching the shape of the PF articular surface becomes increasingly important the larger the expected size of the dowel, and especially with central defects, to avoid mismatch that would complicate or preclude flush seating of the graft. Magnetic resonance images can be sent to most transplant providers for in-house matching of size and shape (eg, Wiberg type).

Once a suitable graft has been obtained, the patient is scheduled for surgery. The window for implantation is usually approximately 2 weeks: bacterial and viral testing generally requires 7-10 days before grafts are released, and chondrocyte viability decreases significantly beyond 4 weeks.15-17

The defect is approached through a medial or lateral parapatellar incision. A lateral approach is preferred to avoid violating the vastus medialis obliquus unless there is lateral instability and a medial patellofemoral ligament imbrication or formal reconstruction is planned; in those cases, a medial approach is used. The authors prefer a lateral retinacular lengthening rather than a lateral release (to maintain lateral “control”). With lateral lengthening, the superficial oblique layer is divided at the lateral aspect of the patella and then

![Figure 2](image-url) Extensive chondrosis of the (A) trochlea and (B) patella. (C) Trochlear defect repaired with the dowel technique and (D) patella resurfaced by the shell technique. Arthroscopy 6 months after operation of the (E) trochlear and (F) patellar grafts.
dissected from the underlying deep transverse layer, which is divided 1-2 cm posterior to the superficial layer incision. This allows a side-to-side closure, which lengthens the lateral tissues by approximately 1-2 cm and importantly still maintains lateral retinacular control of the patella (avoiding iatrogenic medial patellar subluxations).

Once adequate exposure has been achieved, the defects are sized with cylindrical guides that aid in drilling a pin perpendicular to the articular surface at the center of the lesion. The articular cartilage is scored with a punch of the same diameter (ranging from 15-35 mm), and a recipient socket is created with a reamer under continuous cold normal saline irrigation. The total socket depth is approximately 6-8 mm from the articular surface (at least 3 mm of bone), but can be deeper in central trochlear or patellar defects owing to the often very thick cartilage in these locations.

A graft is now fashioned from the corresponding location on the allograft. Particularly with central PF grafts, the orientation of the graft (proximal vs distal) should be verified with a marking pen. The plug graft is obtained with a coring reamer (circular saw), again under constant cold irrigation to avoid thermal damage. Bone marrow elements are removed by pulsatile lavage, and the bony base of the graft is chamfered with a rongeur. The graft is then inserted by hand into the recipient site without the use of a mallet, as

Figure 3 (A) Marked chondrosis of patella, and central trochlea, noting the dysplastic trochlear ridge. (B) Trochlea marked for planned cuts. (C) Trochlear cuts completed. Note that the distal cut is perpendicular to the local articular cartilage tangent to allow uniform osteochondral composite thickness distally as opposed to a tapered cut. (D) Transplanted osteochondral allografts secured with biocompression screws at nonloadbearing margins of patellofemoral articulation.
multiple studies have demonstrated the deleterious effects of excessive forces during graft introduction, that is, chondrocyte death (Fig. 2).18-20

Shell Technique

Similar to the dowel technique, a size-, side-, and compartment-matched graft is obtained. The shell technique may at times be more technically challenging and therefore less frequently used than the dowel technique. The indication is for cartilage defects that are otherwise not amenable to the dowel technique and are not amenable to cell-based therapy.

Shell grafts are a salvage option for young patients with PF arthritis, often owing to long-standing patellar maltracking and instability associated with trochlear dysplasia (Fig. 3A). In these cases, bipolar resurfacing is performed with matched trochlear and patellar grafts from the same donor. Grafts should ideally match the patient in size; a larger graft can be acceptable (it may be trimmed to fit) when a size-matched graft is not available. After exposure as discussed earlier, the defect area is outlined and compared to the donor graft (Fig. 3B). The trochlear cut is made with an oscillating saw. The initial cut starts just above the roof of the intercondylar notch and courses perpendicular to the local articular cartilage for 6-8 mm. The next cut is from medial to lateral or vice versa depending on exposure. The cut is planned to begin at the posterior extent of the first cut and extends proximally to exit just proximal to the proximal extent of the trochlea, which removes the entire native trochlea without “notching” the anterior femoral cortex (Fig. 3C). A corresponding cut is made on the donor trochlea, noting that the thickness will often be different from that of the degenerative or malshaped original. The graft thickness is tailored to minimize allograft bone (minimum is 3-4 mm, allowing hardware fixation) while at the same time matching the distal composite thickness of the host-prepared “bed” distally and anterior femur proximally. The graft is then pulse lavaged to remove bone marrow elements. It is placed on the recipient, cut and trimmed if oversized, then secured with multiple compression screws (often twin-pitched headless screws) at the margins of the articular surface, countersinking them to avoid injury of the opposing articular surface.

Subsequently, a patellar cut is made to remove the articular surface as per arthroplasty techniques. The resultant thickness should not be less than 12 mm, to minimize the risk of patellar fracture, nor larger than 15 mm as this could increase PF contact forces if the final composite patellar thickness is much greater than a standard patellar thickness.21-24 The donor patella is then cut with composite thickness of 6 mm at the medial and lateral margins, noting that with a standard patella the median ridge thickness will obviously be greater.25 The graft is then secured with retrograde screws from the anterior surface of the patella, or countersunk headless, twin-pitched screws at the margins of the articular surface (Fig. 3D). The fixation must be carefully sized and countersunk to avoid potential injury to the opposing articular surface.

Anesthetic

To avoid the morbidity of a femoral nerve block, an adductor canal block (single shot or continuous) in conjunction with a field block (now popular in arthroplasty surgeries) offers excellent pain control and quadriceps function.

Rehabilitation

Isolated PF resurfacing generally does not require prolonged weight-bearing restrictions. Immediate ambulation with the knee locked in full extension is permitted as tolerated. The patients are weaned from the brace when they have full limb muscular control and can walk with a normal gait. Concurrent tibial tuberosity transfer, however, necessitates protection with 4-6 weeks of touchdown weight bearing to minimize the risk of tibia fracture,26 with a full 6 weeks if the transfer is a Fullkerson anteromedialization.

Continuous passive motion is helpful to reduce the risk of stiffness and arthrofibrosis while at the same time aiding cartilage nutritional exchange. Patients start with 0°-40° of range of motion for up to 6 hours a day and should progress quickly with the goal of reaching 90° of flexion within the first week.

Isometric quadriceps exercises (electrical stimulation is a useful augment until full volitional activation is achieved) are begun immediately after surgery. Hip adductor or abductor and core strengthening are to be initiated as mobility and pain allow. Core strengthening and quadriceps strengthening are progressively increased, but deeper squating and lunges are delayed until the possibility of bone collapse has passed (i.e., several weeks for small plugs and many months for shell grafts, especially bipolar.)

Outcomes

Reports on osteochondral allograft transplantation specific to the PF joint are limited. The outcomes are variable and depend largely on the amount of tissue transplanted.27 Overall, outcomes are more guarded than those of the femoral condyle. Interestingly, however, for bipolar procedures, PF transplants have a better survival (though inferior to monopolar) than those in the tibiofemoral compartments.27-30

Reported outcomes for PF osteochondral allograft are in the Table. Some other authors reported PF transplants as part of general case series of knee osteochondral allograft, but specific outcomes were not described.33-35

Conclusions

Fresh osteochondral allograft resurfacing of the PF joint is a challenging procedure owing to the complex anatomy of the central trochlea and patella. With attention to detail and techniques, successful outcomes can be achieved in more than 2/3 of patients. For young patients presenting with advanced degenerative disease, bipolar osteochondral allografting presents
<table>
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<tr>
<th>Study</th>
<th>Total of Knees</th>
<th>Trochlea Patients</th>
<th>Patella Patients</th>
<th>Patellofemoral Patients</th>
<th>Patients Age</th>
<th>Type of Lesion</th>
<th>Allograft Preservation</th>
<th>Technique</th>
<th>Associated Procedures</th>
<th>Follow-Up</th>
<th>Outcomes</th>
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<tr>
<td>Bakay et al&lt;sup&gt;22&lt;/sup&gt;</td>
<td>33</td>
<td>3</td>
<td>8</td>
<td>5</td>
<td>Mean total: 48 y (21-64 y)</td>
<td>Posttraumatic: 3</td>
<td>Cryopreserved</td>
<td>Whole patella, mushroom-shaped technique</td>
<td>Lateral retinacular release in all patients</td>
<td>Total mean: 18 mo (10-38 mo)</td>
<td>1 Failure (fragmentation, patient older than 45 y)</td>
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<td>Chondromalacia: 5</td>
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<tr>
<td>Fitzpatrick and Morgan&lt;sup&gt;31&lt;/sup&gt;</td>
<td>9</td>
<td>3</td>
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<td>Patellar mean 36 (28-50 y)</td>
<td>Patellofemoral</td>
<td>Refrigerated at 4°C with ringer and antibiotics</td>
<td>Whole patella, coronal sectioning</td>
<td>Patella mean: 81 mo (18-123 mo)</td>
<td>2 Excellent, 4 good, 2 fair</td>
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<tr>
<td>Chu et al&lt;sup&gt;30&lt;/sup&gt;</td>
<td>55</td>
<td>5</td>
<td>4</td>
<td>Patellofemoral mean 48 y (26-62 y)</td>
<td>Isolated patella: Chondromalacia</td>
<td>Patellofemoral: 3 Trauma and 1 chondromalacia</td>
<td>Refrigerated at 4°C with ringer and antibiotics</td>
<td>Rectangular pattern using osteotome</td>
<td>Patellofemoral mean: 75 mo (11-147 mo)</td>
<td>Isolated patella: 1 Excellent and 4 good Patellofemoral: 3 Excellent and 1 failure (failed graft incorporation)</td>
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<td>Karaglis and Learmonth&lt;sup&gt;32&lt;/sup&gt;</td>
<td>5</td>
<td>1</td>
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<td>27 y</td>
<td>Avascular necrosis</td>
<td>Fresh frozen non-irradiated</td>
<td>Mega-OATS (30 × 30 mm)</td>
<td>Elmslie-Trillat + lateral release</td>
<td>Total mean: 32.8 mo (30-36 mo)</td>
<td>Lysholm improved from 47-99 and Tegner from 3-7</td>
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<td>Jamali et al&lt;sup&gt;27&lt;/sup&gt;</td>
<td>20</td>
<td>8</td>
<td>12</td>
<td>Patellar subluxation: 7 Primary Posttraumatic: 6 Patellofemoral arthrosis: 4 Chondromalacia: 3</td>
<td>42 y (19-64 y)</td>
<td>Patellofemoral</td>
<td>Refrigerated at 4°C in tissue culture medium</td>
<td>Trochlea: Shell, whole trochlea (all)</td>
<td>Patella: 15 whole patella and 3 cylindrical plug (2 missing data)</td>
<td>Patellofemoral mean: 94 mo (24-214 mo)</td>
<td>5 Failures (2 revision allograft, 2 TKA and 1 arthrodesis)</td>
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<td>Spak and Teitge&lt;sup&gt;40&lt;/sup&gt;</td>
<td>14 (11 patients)</td>
<td>2</td>
<td>12</td>
<td>37 y (24-56 y)</td>
<td>Arthritis secondary to trauma, bony malalignment, patellar instability or iatrogenic cartilage shaving</td>
<td>Within 24 hours in ice water</td>
<td>Trochlea and patella: Shell, whole articular surface 2 patients had previous patellectomy</td>
<td>2 Femoral osteotomies and 1 tibial osteotomy</td>
<td>Total mean: 10 yr (2.5-17.5 yr)</td>
<td>Graft survival (8 knees): 4 Knees more than 10 y, 2 more than 5 y and 2 more than 2 y Failures (6 knees): 2 Graft failures, 3 tibiofemoral degeneration in patients with bipolar graft needing TKA after 10 y; and 1 recurrent patellar instability in a patellar unipolar graft</td>
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TKA: total knee arthroplasty, HSS: hospital for special surgery score, KSS: knee society score.
a salvage option, and should be combined with concurrent procedures to address patellar maltracking and instability.

References