Magnetic Resonance Imaging and Clinical Evaluation of Patellar Resurfacing With Press-Fit Osteochondral Autograft Plugs

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Background: Autologous osteochondral transplantation (AOT) has been successfully used in the femoral condyle and trochlea and is an attractive treatment option for full-thickness patellar cartilage lesions.

Hypothesis: Patients treated with AOT for the repair of symptomatic, isolated patellar cartilage lesions will demonstrate improvement in functional outcomes and postoperative magnetic resonance imaging appearance.

Study Design: Case series; Level of evidence, 4.

Methods: Between 2002 and 2006, patients with focal patellar cartilage lesions treated with AOT were prospectively followed. The mean age at the time of surgery was 30 years. Clinical assessment was performed with the International Knee Documentation Committee (IKDC), activities of daily living of the Knee Outcome Survey (ADL), and Short Form-36 (SF-36) at baseline and most recent follow-up. Magnetic resonance imaging was used to evaluate the cartilage repair morphologic characteristics in 14 cases.

Results: Twenty-two patients met the study criteria with a mean follow-up of 28.7 months (range, 17.7-57.8 months). The mean patellar lesion size was 165.6 ± 127.8 mm^2, and the mean size of the donor plug was 9.7 ± 1.1 mm in diameter with 1.8 ± 1.4 plugs/defect. The mean preoperative IKDC score was 47.2 ± 14.0 and improved to 74.4 ± 12.3 ($P = .028$). The mean preoperative ADL score was 60.1 ± 16.9 and increased to 84.7 ± 8.3 ($P = .022$). The mean SF-36 also demonstrated an improvement, from 64.0 ± 14.8 at baseline to 79.4 ± 15.4 ($P = .059$). Nine patients underwent concomitant distal realignment and demonstrated improvement between preoperative and postoperative outcomes scores, but these differences were not statistically significant. Magnetic resonance imaging appearance demonstrated that 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.

Conclusion: Patellar AOT is an effective treatment for focal patellar chondral lesions, with significant improvement in clinical follow-up. This study suggests that patients with patellar malalignment may represent a subset of patients who have a poor prognostic outlook compared with patients with normal alignment.

Keywords: patella; focal chondral defect; cartilage injury; osteochondral autograft; mosaicplasty

Focal patellar chondral lesions have been treated with a multitude of techniques in the past, but none has provided reliable and consistent symptomatic relief. The treatment of patellar cartilage lesions has changed with a greater understanding of patellofemoral biomechanics, as well as the development of cartilage repair techniques. Patellar chondral defects have historically been difficult to treat, but the emergence of cartilage repair has provided many more potential treatment options, including microfracture,[31] autologous chondrocyte implantation,[27] osteochondral autograft and mosaicplasty,[2,10] and osteochondral allograft.[6]

Autologous osteochondral transplantation (AOT) provides intact hyaline cartilage and represents an attractive option for full-thickness cartilage defects. Although numerous studies have examined the clinical results of patients

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treated with AOT, there are no studies that have specifically reviewed the clinical outcome of patients treated with a cartilage repair procedure for patellar lesions. The preferred cartilage repair technique of these lesions at our institution is AOT.

The ability of MRI to detect articular cartilage lesions has dramatically improved. Recent developments in cartilage-sensitive pulse sequences allow visualization of articular cartilage appearance and assessment of the extracellular matrix with a high degree of accuracy and reproducibility.[28]

Magnetic resonance imaging is also able to provide insight into the ultrastructure of articular cartilage, detecting early degenerative changes before discernible thickness loss on conventional MRI. T2 relaxation time mapping is used to assess the collagen component of the extracellular matrix.[32] In magnetic resonance microscopy systems, T2 mapping has been shown to correlate with collagen orientation within articular cartilage.[32] As a result, the T2 profile in normal cartilage is a reflection of the different histologic zones, with T2 values (in milliseconds) appearing shortest in the deep (or radial) zone, where collagen is most highly ordered and oriented perpendicular to the articular surface and subchondral plate. T2 values are relatively higher in the transitional zone, where the collagen fibers have a more random orientation. In the superficial zone, where the collagen is again highly ordered, T2 values are short. At the current time, the thin superficial zone remains beyond the resolution of MRI scanners at clinically relevant field strengths.

Magnetic resonance imaging with dedicated pulse sequences can provide a noninvasive and objective method to evaluate cartilage repair procedures over the surgically manipulated cartilage, the adjacent and opposite cartilage, as well as the site of peripheral integration.

The purpose of the present study was to prospectively analyze the clinical outcome and the MRI appearance of patients treated using AOT for the repair of isolated symptomatic full-thickness cartilage lesions of the patella.

TABLE 1
Information on 22 Patients Entered in the Study

Characteristic	No. of Patients (%)
Sex	
Male	12 (55)
Female	10 (45)
History of trauma	
Yes	10 (45)
No	12 (55)
Cause	
Osteoarthritis/malalignment	9 (41)
Chondral lesion	6 (27)
Osteochondritis dissecans lesion	5 (23)
Dislocation	2 (9)
Mean cartilage lesion size	165.6 ± 127.8 mm^2
Location of lesion	
Lateral facet	9 (41)
Central ridge	6 (27)
Medial facet	5 (23)
Inferior pole	2 (9)
Number of plugs	1.8 ± 1.4
Plug diameter (mm)	9.7 ± 1.1
Plug depth (mm)	13.3 ± 2.4
Additional procedures	
Lateral release	13 (59)
Distal realignment	9 (41)
Proximal realignment	3 (15)

MATERIALS AND METHODS

The Cartilage Registry prospectively collects data on all patients who have had cartilage repair procedures performed at a single institution. This study was approved by the Institutional Review Board. From September 2002 to January 2006, 90 patients underwent AOT procedures, and 68 cases involved either the femoral condyle or trochlea. The remaining 22 patients underwent patellar AOT with or without tibial tubercle osteotomy.

In a retrospective review of prospectively gathered data, patients with a symptomatic, isolated patellar cartilage lesion who underwent patellar osteochondral autograft transplantation and were refractory to conservative treatment (including physical therapy, anti-inflammatory drugs, and bracing) met the inclusion criteria. Patients presented with complaints of acute or chronic anterior knee pain. A comprehensive physical examination was performed to evaluate patellar pain, subluxation, tilt, apprehension, crepitus, and tracking. Plain radiographs with 45° posteroanterior and flexion views and Merchant views were obtained to evaluate patellar tilt. Patients with patellofemoral pain underwent a course of physical therapy focused on closed-chain quadriceps strengthening and hamstring stretching; patients who failed to improve with physical therapy underwent fast spin-echo MRI with cartilage-sensitive pulse sequences of the affected knee. The patients who underwent simultaneous distal realignment had clinical evidence of patellofemoral malalignment according to surgeon preference. Patients who had additional cartilage lesions in the femoral condyle or tibial plateau, correction of varus or valgus malalignment, or concomitant ligament reconstruction were excluded from the study.

Twenty-two patients met the study criteria and were reviewed in the present study (Table 1). There were 55% male and 45% female patients, with an average age (± standard deviation) of 30 ± 12 years (range, 15-57 years) at the time of surgery. The mean body mass index was 24.9 ± 5.2 kg/m^2 (range, 17-36 kg/m^2). The indications for surgery were patellofemoral malalignment (40.9%, n = 9), isolated cartilage lesion (27.3%, n = 6), osteochondritis dissecans (22.7%, n = 5), or patellar dislocation (9.1%, n = 2). Forty-five percent (n = 10) of cases were related to trauma, and 55% (n = 12) were nontraumatic. Fourteen patients had failed previous knee arthroscopy and patellar chondral debridement. Additional procedures that were performed included lateral release[23] (n = 13), distal realignment[5] (n = 9), and proximal realignment[33] (n = 3). Concomitant procedures, including distal realignment, were performed according to surgeon preference. All patellar lesions were

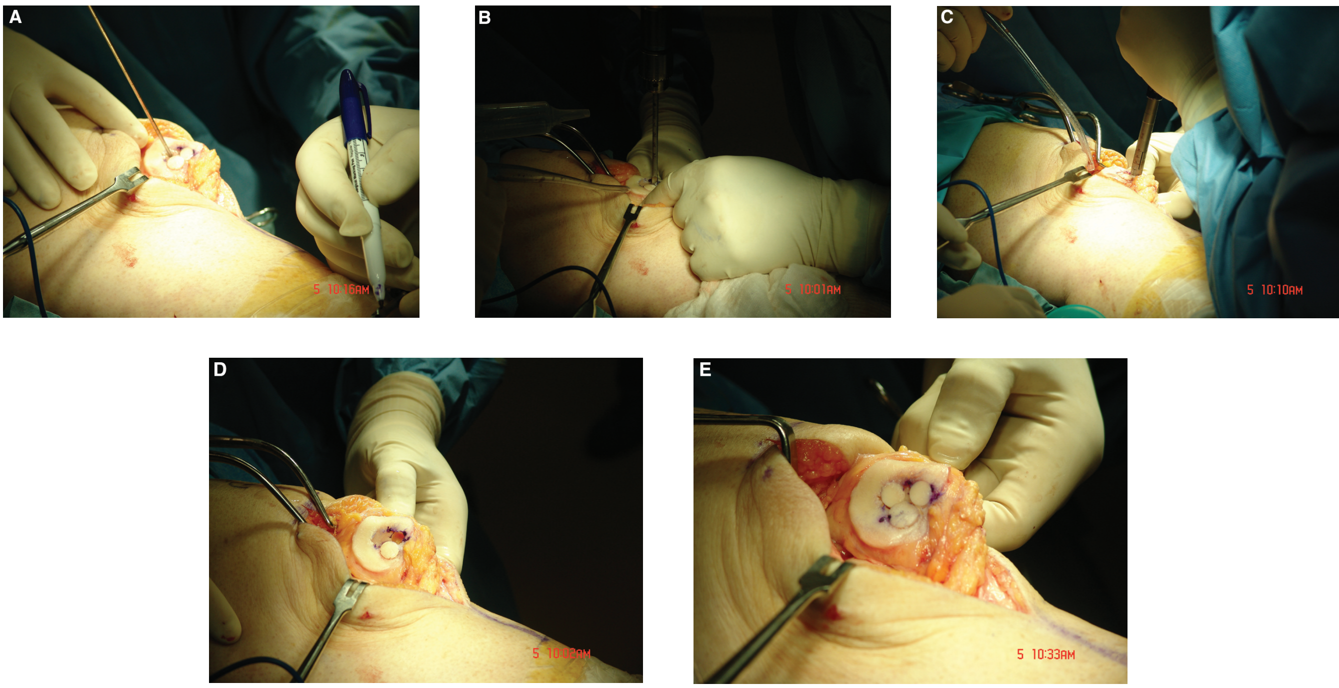

Figure 1. Surgical technique for patella osteochondral autograft transfer. A, insertion of the guide pin perpendicular to the plane of the articular cartilage. B, drilling of the lesion with the flat acorn and stop at the far cortex. C, insertion of the cannulated chisel to remove excessive bone. D, final defect after removal with chisel and debris removal with curette. E, final result with osteochondral plug in place on the medial facet of the patella.

Outerbridge grade III/IV, with a mean surface area of 165.6 ± 127.8 mm^2 (range, 72-500 mm^2).

Surgical Procedure

All surgical procedures were performed by 5 fellowship-trained orthopaedic surgeons (including T.L.W., R.F.W., R.J.W.) with extensive experience in cartilage repair procedures. A diagnostic arthroscopy was performed to assess the cartilage lesion and any other intra-articular pathologic abnormalities. A 2.5-in parapatellar incision was made beginning at the inferior pole of the patella to the superolateral border of the patella. Once the arthrotomy was complete, the patella was everted, and the articular surface was meticulously examined to characterize the location, size, and Outerbridge grade of the chondral and subchondral lesions. Using the osteochondral autograft transfer system (OATS, Arthrex Inc, Naples, Fla), a guide wire was drilled in the central portion of the cartilage defect, and the power reamer was carried down to a depth of 10 to 15 mm over the guide wire (Figure 1). The recipient site was predrilled 1 to 2 mm smaller than the harvester. A punch guide was selected with a diameter that was large enough to encompass the chondral defect in its entirety. The recipient punch guide was then tapped down to the subchondral surface of the patella, and the depth of the osteochondral plug was measured. The base of the recipient site should be flat and free of debris to allow for appropriate plug fit. The donor osteochondral plug was harvested from the superior aspect of the lateral trochlear in all cases. A donor punch guide of the same diameter as the recipient punch guide was malleted down to the same depth as the recipient plug. The donor osteochondral plug was press-fit into the recipient site and gently impacted with a mallet until continuous with the surrounding articular surface. In 9 patients, the donor sites were left empty. In the remaining 11 patients, TruFit CB biosynthetic plugs (OsteoBiologics, San Antonio, Tex) composed of polylactide-co-glycolide, calcium sulfate, and polyglycolide fibers were used to fill the donor site. The biosynthetic plug of the same diameter as the donor plug was then press-fit into the donor site and contoured to the surrounding surface.

The most commonly used size of the donor plug was 10 mm. The mean size of the donor plug was 9.7 ± 1.1 mm (range, 6-11 mm) in diameter and 13.3 ± 2.4 mm (range, 9-15 mm) in depth. The mean number of plugs/defect was 1.8 $\pm$ 1.4 (range, 1-7), and there were 14 patients with 1 plug, 6 patients with 2 plugs, 1 patient with 4 plugs, and 1 patient with 7 plugs. Distal realignment was performed according to the technique described by Fulkerson.[5]

In the recovery room, continuous passive motion from 0° of extension to 60° of flexion was initiated with adequate analgesia and could be advanced to 90° of flexion as tolerated. The patient was partially weightbearing in a hinged knee brace locked at 0° of extension with the assistance of crutches. At 6 weeks after the operation, the patient was advanced to full weightbearing out of the brace, and the patient focused on quadriceps strengthening and knee extension under the supervision of a physical therapist. The patient was instructed to avoid full knee extension against resistance but could use the leg press and perform straight leg raises.

Functional Outcome Evaluation

As per the Cartilage Registry protocol, an independent observer collected the data before surgery and at most recent follow-up. The clinical assessment was performed with validated, knee-specific outcome instruments after knee articular cartilage repair[21] and included the International Knee Documentation Committee (IKDC), activities of daily living of the Knee Outcome Survey (ADL),[13] and the Medical Outcome Study 36-Item Short Form Survey (SF-36).[22]

Magnetic Resonance Imaging

Magnetic resonance imaging was performed on a 1.5-T or 3.0-T clinical imaging system (General Electric Healthcare, Milwaukee, Wis), using either a linear receive-only knee extremity coil or a multichannel transmit-and-receive phased-array coil. Fast spin-echo images were obtained in 3 planes to assess articular cartilage using a previously validated cartilage-sensitive pulse sequence.[29] The moderate echo time (TE) used to acquire images allowed for high-contrast resolution between articular cartilage, subchondral bone, and joint fluid, while avoiding the susceptibility artifacts of the postoperative knee seen in gradient echo imaging techniques. All images were obtained with a repetition time (TR) of 3500 to 6000 milliseconds, TE of 34 milliseconds (effective), field of view of 13 to 16 cm^2, and matrix of 512 × 256 to 416, providing minimum in-plane resolution of 254 μm in the frequency direction by 312 μm in the phase direction by slice resolution of 3 to 3.5 mm with no gap. A wider receiver bandwidth of 31.2 to 62.5 kHz was used over the entire frequency range to minimize chemical shift misregistration. The presence of subchondral bone marrow edema was assessed with the use of an additional fat-suppressed pulse sequence in the sagittal plane.

T2 mapping was performed using a multislice, multiecho modified CPMG pulse sequence, which uses interleaved slices and tailored refocusing pulses to minimize contribution from stimulated echoes.[20] Standard T2 mapping pulse sequence parameters used were a TR of 800 milliseconds, 8 echoes sampled using sequential multiples of the first TE (9-10 milliseconds), field of view of 16 cm^2, and matrix of 256 to 384 × 256, providing a minimum in-plane resolution of 254 μm in the frequency direction by 312 μm in the phase direction, by slice resolution of 2.0 to 3.0 mm with no gap, and a receiver bandwidth of 62.5 kHz. After image acquisition, data sets were analyzed on a pixel-by-pixel basis with a 2-parameter weighted least-squares fit algorithm, assuming a monoexponential fit (Functool 3.1, General Electric Healthcare). Quantitative T2 values were calculated by taking the natural logarithm of the signal decay curve in a selected region of interest. Regions of interest were obtained in a standardized fashion, from the articular cartilage over the osteochondral plug, at the interface, as well as of the adjacent and opposite articular cartilage surfaces.

All MRI studies were read by a single experienced musculoskeletal radiologist without knowledge of the surgical procedure, patient, or treating surgeon.[3] The images were scored according to a previously described cartilage repair criteria: signal intensity of the repaired area relative to the surrounding cartilage (hypointense, isointense, or hyperintense), morphologic appearance (depressed, flush, or proud), subchondral edema (none, mild, moderate, or severe), bony overgrowth (absence or presence), interface with adjacent cartilage (absence, presence, size of fissure), percentage of fill based on both coronal and sagittal images (0%-33%, 34%-66%, or 67%-100%), integrity of adjacent cartilage (modified International Cartilage Repair Society [ICRS] classification),[12] integrity of opposite cartilage (modified ICRS classification), trabecular integration (none, partial, or complete), fat-pad scarring (mild, moderate, or severe), and signal of bone graft (fat, edema, fibrosis).[3]

Statistical Analysis

Statistical analysis to compare outcome scores before and after surgery was performed using 2 related-samples comparison with nonparametric Wilcoxon signed rank test (SPSS Inc, Chicago, Ill). A P value of < .05 was considered to be significant.

RESULTS

From September 2002 to July 2006, 22 patients with a mean follow-up of 28.7 months (range, 17.7-57.8 months) underwent patellar osteochondral autograft. All patients revealed improvement in clinical outcome scores compared with baseline (Figure 2A). The mean preoperative IKDC score was 47.2 ± 14.0 (range, 20.7-71.3) and improved to 74.4 ± 12.3 (range, 51.7-87.4) at follow-up (P = .028). The mean preoperative ADL score was 60.1 ± 16.9 (range, 23.8-93.8) and increased to 84.7 ± 8.3 (range, 65.0-93.7) postoperatively (P = .022). The mean SF-36 also demonstrated an improvement, from 64.0 ± 14.8 (range, 39.1-85.6) at baseline to 79.4 ± 15.4 (range, 43.8-92.0) at follow-up (P = .059), but failed to reach statistical significance.

Nine patients underwent simultaneous distal realignment at the time of patella AOT (AOT + DR). Although the functional outcomes of patients who underwent AOT + DR did increase after surgery, this improvement from the baseline score was not statistically significant (Figure 2B). On the contrary, the patients who underwent isolated patellar AOT (AOT alone, without DR) demonstrated a significant improvement in IKDC scores (P = .009) at most recent follow-up, but the SF-36 (P = .066) and ADL (P = .056) did not reach statistical significance. The mean baseline scores for the AOT-alone group were lower compared with the AOT + DR group in all outcome measures, but these differences were not statistically significant. The AOT-alone group had greater mean postoperative scores than the AOT + DR group; however, these differences were not significant.

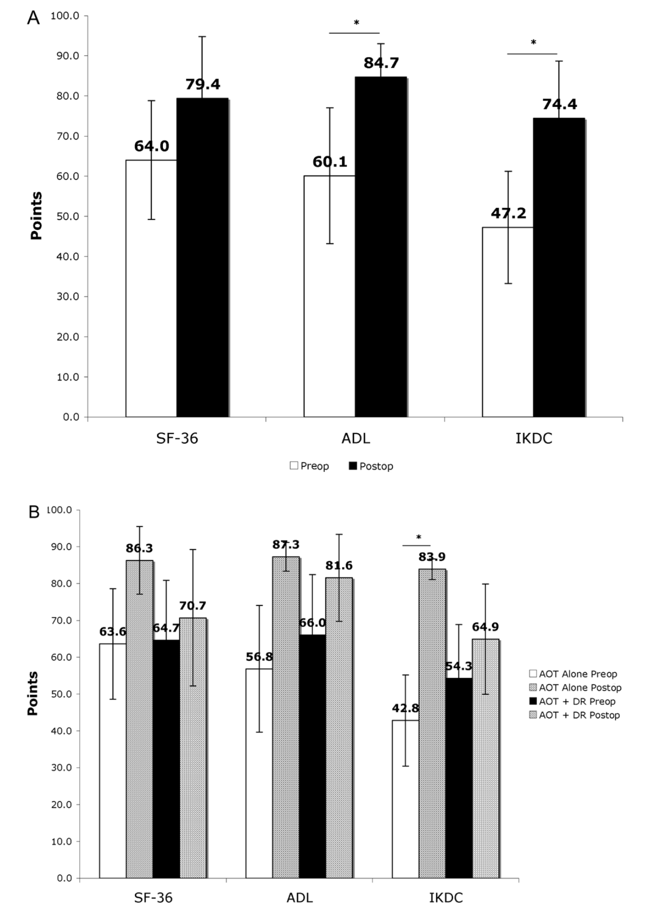

Figure 2. Functional outcome evaluation. A, outcome assessment before and after patellar osteochondral transplantation with Short Form 36 (SF-36), activities of daily living of the Knee Outcome Survey (ADL), and International Knee Documentation Committee (IKDC) scores. B, outcome assessment comparing preoperative and postoperative scores between patellar osteochondral transplantation without (AOT Alone) and with distal realignment (AOT + DR). *Denotes $P < .05$ between scores.

Three of the 9 patients who had a concomitant tibial tubercle osteotomy had hardware removed at a mean of 9.7 months (range, 5-14 months) after the initial surgery. One patient had an arthroscopic debridement of the medial facet of the patella and repeat lateral release 1 year after AOT of the central aspect of the patella. This particular patient had a very large defect (500 mm^2) located in the central ridge with extension to the medial and lateral facets and required 4 osteochondral plugs. Although there was good incorporation of the trabecular portion of the plug, the articular surface of the osteochondral plugs demonstrated grade 3 ICRS chondromalacia, with fissures between plugs and plug-host cartilage interface. The case was a salvage procedure for a massive patellar lesion in an adolescent patient and represents a failure secondary to the extent of the index cartilage lesion.

There were a total of 24 postoperative MRI examinations performed on 14 patients to assess the healing of the osteochondral autograft. The most recent MRI scans for the 14 patients were obtained at a mean follow-up of 17.3 months (range, 4.9-33.2 months) and are presented in Table 2. In addition to the initial postoperative MRI scan, 7 patients had 10 additional serial MRI examinations with a mean of 2.4 scans (range, 2-3 scans).

In all 14 patients, there was 67% to 100% cartilage repair fill, but there was also a mismatch between the subchondral plate of the plug and the surrounding native patella. The plug appearance was flush with the surrounding

TABLE 2
Most Recent Magnetic Resonance Imaging (MRI) After Patella Osteochondral Autograft Transplantation[a]

MRI Finding	No. of Knees (%)
Signal intensity	
Isointense	6 (42.9)
Hyperintense	8 (57.1)
Hypointense	0 (0)
Appearance of osteochondral plug	
Flush	10 (71.4)
Depressed	0 (0)
Proud	4 (28.6)
Subchondral edema	
None	5 (35.7)
Mild	4 (28.6)
Moderate	4 (28.6)
Severe	0 (0)
Interface with adjacent cartilage	
Smooth	0 (0)
Fissures <2 mm	9 (64.3)
Fissures >2 mm	5 (35.7)
Repair cartilage fill	
Good (67%-100%)	14 (100)
Moderate (34%-66%)	0 (0)
Poor (0%-33%)	0 (0)
ICRS adjacent cartilage	
Normal	1 (7.1)
Grade 1	7 (50.0)
Grade 2	5 (35.7)
Grade 3	1 (7.1)
Grade 4	0 (0)
ICRS opposite cartilage	
Normal	6 (42.9)
Grade 1	5 (35.7)
Grade 2	1 (7.1)
Grade 3	2 (14.2)
Grade 4	0 (0)
Fat-pad scarring	
Mild	13 (92.9)
Moderate	1 (7.1)
Severe	0 (0)
Trabecular incorporation	
Complete	10 (71.4)
Partial	4 (28.6)
None	0 (0)
Signal of bone graft	
Fat	12 (85.7)
Edema	2 (14.3)
Fibrosis	0 (0)

[a]ICRS, International Cartilage Repair Society. All plugs (N = 14).

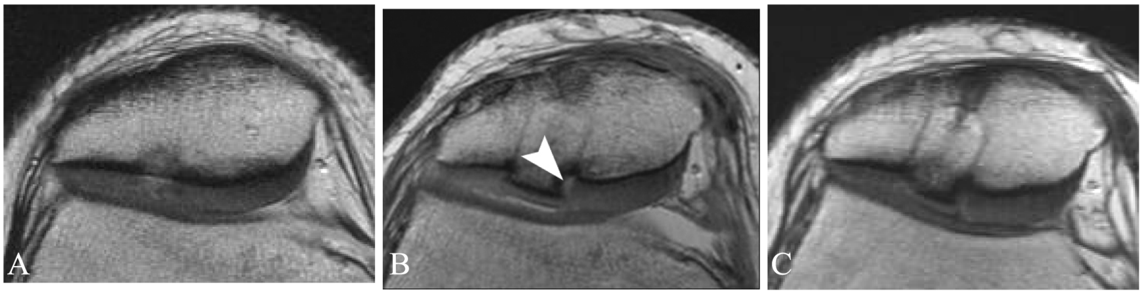

Figure 3. Axial cartilage sensitive fast spin-echo magnetic resonance images in an 18-year-old patient with a patellar autologous osteochondral plug. Before surgery (A), a focal full-thickness cartilage defect affecting the central lateral patellar facet was demonstrated. Four months after surgery (B), the repair cartilage was flush with adjacent native cartilage and isointense signal, despite the offset of the underlying subchondral plate and tidemark. A large fissure was noted at the medial interface (white arrowhead). Sixteen months after surgery (C), the repair cartilage remained isointense. The medial fissure had filled in with presumed reparative fibrocartilage.

cartilage in 10 patients and proud in 4 patients. There were no cases with a smooth transition between host and donor cartilage, and fissures were <2 mm in 9 cases and >2 mm in 5 cases. The cartilage signal of the osteochondral plugs was observed as hyperintense in 8 of 14 cases and isointense in the remaining 6 cases. There was no evidence of subchondral edema in 5 cases, but subchondral edema was observed to be mild in 4 cases and moderate in 4 cases.

The ICRS cartilage grade of the adjacent native cartilage appeared to have partial-thickness cartilage surface change in the majority of cases, with grade 1 in 7 cases and grade 2 in 5 cases. The adjacent host cartilage appeared to be ICRS grade 3 in 1 patient. There was only 1 case with normal cartilage. In most cases, the trochlear cartilage opposite the osteochondral plug was considered to be normal (ICRS grade 0) or with only minimal surface fibrillations (ICRS grade 1) in 6 and 5 cases, respectively. One patient had ICRS grade 2 change, and an additional 2 patients had ICRS grade 3 change in the opposing trochlear cartilage.

Some observations can be ascertained from the 7 patients with serial MRI examinations. Five of the 7 cases demonstrated a reduction in the subchondral edema pattern over time. The signal intensity of the repair cartilage was stable in 5 cases and changed from hyperintense to isointense in 1 case. One patient demonstrated an increase in signal of repair cartilage from isointensity to hyperintensity. The interface between donor and host cartilage appeared to be stable across time, and there was only 1 patient who demonstrated an increase in the size of the fissure from <2 mm to >2 mm (Figure 3).

T2 mapping was performed in 10 plugs. Prolongation of T2 values relative to normal cartilage, indicating less organized collagen fiber orientation, was seen in all cases. Notable percentage differences between the T2 values comparing repair and normal cartilage were demonstrated. In the 6 plugs where the articular cartilage overlying the plug was hyperintense relative to normal cartilage, T2 relaxation times were prolonged in all cases, with a mean percentage difference of 40.9% (range, 27.5%-60.8%). In the 4 plugs that demonstrated isointense cartilage signal, 2 demonstrated T2 values that were closer to normal cartilage, with a mean percentage difference of 9.5% (range, 6.2%-12.8%). In the remaining 2 patients, there was a notable prolongation of T2 values, with a mean percentage difference of 31.7% (range, 27.8%-35.6%); these elevated values lie within the lower range measured for hyperintense cartilage. The latter data suggest a breakdown in the collagen component in the extracellular matrix that occurs before visible changes of cartilage degeneration, as detected on the gray scale observed on the morphologic cartilage-sensitive MRI (Figure 4). In all 10 cases, there is expected marked T2 prolongation at the repair interface, with a mean percentage difference of 63.8% (range, 25.2%-98.5%), suggesting less organized collagen orientation (Figure 4).

DISCUSSION

There are a number of published studies on AOT,[§] but only a few have specifically reported on the results of the patella.[1,10,15] Those studies have indicated that osteochondral plugs transferred to the patella have not been as successful as plugs transferred to the femoral condyles. Hangody and Fules[10] combined the results of patellar and trochlear osteochondral plug transfers, and the group had 79% good to excellent results compared with the 92% good to excellent results in the femoral condyle group. Bentley et al[1] observed that patellar mosaicplasty patients had fair to poor arthroscopic appearance and 60% good to excellent results using the modified Cincinnati and Stanmore scores; thus, the authors concluded that chondral lesions of the patella were contraindicated for osteochondral autografting. They believe that the difference in articular cartilage thickness between the trochlea (donor) and patella (host) is the primary reason for failure and that the structural organization of trochlea cartilage is not adapted for the mechanical environment of the patellofemoral joint.[1] In another study, 7 of 37 cases of lateral patellar malalignment were treated with AOT and either a lateral release or Elmslie-Trillat procedure. The investigators did not observe

[§]References 1, 4, 8, 10, 11, 14, 17, 19, 26, 30

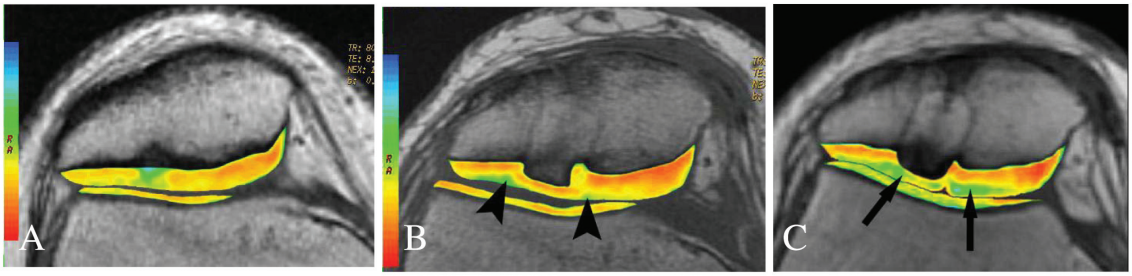

Figure 4. Corresponding axial T2 relaxation time maps in an 18-year-old patient with a patellar autologous osteochondral plug (same patient as in Figure 3). The color maps are coded to capture T2 values ranging from 10 to 90 milliseconds, with orange/red reflecting the shorter values and green/blue reflecting longer T2 values. Before surgery (A), expected focal T2 prolongation is seen at the site of the full-thickness cartilage defect. The adjacent cartilage demonstrates normal color stratification. Four months after surgery (B), the repair cartilage maintains color stratification of normal cartilage. The repair-native interface and adjacent cartilage, however, demonstrate T2 prolongation (black arrowheads). Sixteen months after surgery (C), marked and more diffuse T2 prolongation is demonstrated over the repair and adjacent cartilage (black arrows), despite normal appearance and signal in Figure 3C. The opposite cartilage also demonstrates similar prolongation of T2 values, compared with before.

a correlation with the site of chondral location, and the mean postoperative Tegner score was 3.76 and ADL score was 72.3.[15] There are 2 separate case reports of press-fit autologous osteochondral plugs for isolated patella lesions, and both report that the patients were asymptomatic with good cartilage surface and subchondral bone integration at 6-month MRI examination.[18,30]

With the advent of cartilage repair techniques, there are potentially more options to treat patellofemoral chondral lesions. Challenges exist, however, as certain aspects of AOT are more complicated in the patella. Restoration of the patellar articular surface contour can be complicated depending on the location of the lesion. The preparation of the recipient site must be performed perpendicular to the surface, and the surface congruity of the donor site should attempt to resemble the recipient site. The plug should be gently tapped until flush with the surrounding surface. Of the 4 patients with a proud plug, 3 also had a distal realignment at the time of patella AOT. In 1 case, the donor plug was intentionally left 1 mm proud to account for postperative settling, but the plug remained proud at 29.7-month follow-up. Although subsidence has been reported to occur in a third of cases treated with mosaicplasty in weightbearing areas, there was only 1 case of a depressed plug appearance.[9] The decreased likelihood of subsidence may be because of the press-fit technique or the patella location. When tibial tubercle osteotomy is performed with AOT, the plug should be flush with the surrounding cartilage, as these are unlikely to settle over the course of time.

When implanted in a press-fit technique, the osseous portion of the osteochondral plug heals in a predictable fashion. The plug usually demonstrates a reduction in subchondral edema and trabecular incorporation with the surrounding bone, and 7 of 9 (77.8%) of our cases were completely incorporated at greater than 12 months. There was 1 case with partial trabecular incorporation at 6.0 months, 12.5 months, and 23.5 months after AOT and simultaneous tibial tubercle osteotomy. There were 2 cases with greater than 4 plugs, and both cases also demonstrated complete trabecular incorporation. Expectant healing of the subchondral bone has also been described in animal MRI studies and histologic specimens.[7,16,25]

Patellar cartilage is thicker than cartilage in other areas of the knee; thus, there is a "step-off" between the cartilage thickness of donor plugs from the lateral trochlea ridge and the recipient patellar cartilage. The subchondral bone of the donor plug extends past the tidemark of the surrounding articular cartilage, causing a difference in contact loads; this may have contributed to the hyperintense cartilage signal seen in 57.1% of cases. Biomechanical indentation demonstrates stiffness related to cartilage thickness[16]; thus, thin cartilage from the trochlea is stiffer than the thick cartilage of the surrounding patella and may not be appropriate for the contact and shear stresses of the patellofemoral joint. The ideal osteochondral transfer involves a plug of the same surface geometry, cartilage thickness, and subchondral bone modulus as the recipient osteochondral composition. Although a direct relationship has not been established, it can be surmised that the differential make-up of osteochondral tissue between plug (donor) and patella (host) leads to a suboptimal outcome. The marked T2 prolongation at the repair interface for all T2-mapped MRI examinations suggests less collagen fiber orientation in disorganized repair tissue at the donor-host junction as a result of the different contract stresses of the plug and surrounding native patella. Additionally, the quantitative T2 profile of the donor plug cartilage architecture does not precisely match the surrounding recipient architecture. The transplantation of an osteochondral plug of the same cartilage thickness is critical to create a mechanical and biologic environment that is most conducive to cartilage incorporation,[1] but this is not usually possible because of the inherently thicker cartilage over the patella.

The chondral portion of the osteochondral plug does not appear to show evidence of peripheral healing over time. All the plugs demonstrated 67% to 100% cartilage fill at all time points without evidence of deterioration. There were no cases with a smooth cartilage interface, and the size of the fissure remained the same size over time in most cases. In 1 of 7 cases, the cartilage interface increased from less than to greater than 2 mm, and the cartilage signal normalized to isointense from 10.4 to 16.1 months. That same case also demonstrated progression to more complete trabecular incorporation over the same time. In a rabbit study, femoral condylar lesions (5-mm diameter) that were implanted with osteochondral plugs obtained from the contralateral femoral condyle (6-mm diameter) revealed progressive cartilage integration until a gap was no longer apparent at 12 weeks.[24] These findings suggest that the cartilage surface of the osteochondral plug can incorporate with the surrounding articular surface when the surface geometry and cartilage width are identical and the donor plug is press-fit with a diameter 1 mm greater than the recipient site or that the rabbit model has a better capacity to heal cartilage injury.

Horas et al[11] performed second-look arthroscopy in 3 patients, and a persistent, circular gap was evident around the plug at the level of the cartilage, but the macroscopic appearance of the donor cartilage was indistinguishable from the host cartilage. Between 3 months and 22 months, biopsy specimens obtained at the interface revealed a cleft from the articular surface to the level of the subchondral bone.[11] Despite the persistent cleft, a number of studies have demonstrated that the proteoglycan synthesis and content, collagen type, tissue cellularity, and chondrocyte viability of the autologous osteochondral plug can resemble normal hyaline cartilage.[7,11,16] Longer term follow-up is required to determine the effect of fissures at the cartilage interface and its effect on the surrounding and opposite articular surfaces.

Patients with patellar malalignment and lateral facet chondromalacia appear to be a subgroup of patients with poorer outcomes compared with patients with isolated chondral lesions secondary to osteochondritis dissecans or trauma. Although subgroup analysis by cause was not performed, the subgroup analysis by procedures of isolated patellar AOT and patellar AOT + DR effectively compares the different causes. There were only 9 patients in the AOT + DR group, and all 9 were treated for patellofemoral malalignment. The 13 patients in the isolated patella AOT group had isolated cartilage lesion (n = 6), osteochondritis dissecans (n = 5), or patellar dislocation (n = 2) without evidence of malalignment. The evaluation and treatment of patellofemoral joint pathomechanics are paramount to a successful outcome. Although the patients with concomitant distal realignment demonstrate improvement in functional outcomes, these patients do not reach the same level of improvement as the patients with isolated patella AOT. These findings are likely to reflect a difference in patellofemoral lesions rather than a difference in surgical technique. Patients with an isolated patellar cartilage lesion without malalignment appear to show marked improvement after AOT. Tibial tubercle osteotomy should only be performed if there is evidence of patellofemoral malalignment in the setting of a chondral lesion.

There are a number of limitations of the present study. The study was designed to be a retrospective review of data collected prospectively in a registry after cartilage repair procedures. We acknowledge that the MRI data are incomplete because of the retrospective nature of the study and, therefore, prone to selection bias. Although a prospective follow-up of the same patients at identical, standardized time intervals would have been ideal, a prospective study for an uncommonly performed procedure would have been impractical and would require a lengthy study period to accumulate an adequate cohort. Because AOT of the patella is an uncommon procedure, the sample size is small, and the study is, therefore, underpowered for subgroup analysis. Despite an incomplete follow-up, the imaging provides an objective observation of the maturation of autologous osteochondral plugs in the patella, and the results reflect the observation of changes in appearance and T2 values over time.

CONCLUSION

Patellar AOT is an effective treatment for focal patellar chondral lesions with significant improvement in clinical follow-up. The osseous component of the osteochondral plug appears to heal predictably, but the interface between the plug and host cartilage does not completely integrate and may widen over time. This study suggests that patients with patellar malalignment may represent a subset of patients who have a poor prognostic outlook compared with patients with patellar lesions associated with isolated cartilage lesions due to frank patellar dislocation, trauma, or osteochondritis dissecans.

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