A commentary by Darren de SA, MD, FRCSC, and Freddie H. Fu, MD, is linked to the online version of this article at jbjs.org.

Clinical and MRI Outcomes of Fresh Osteochondral Allograft Transplantation After Failed Cartilage Repair Surgery in the Knee

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Background: Fresh osteochondral allograft transplantation is an appealing option to address a failed cartilage repair surgical procedure, given the ability to treat large lesions and to address the subchondral osseous changes commonly seen in the revision setting. We hypothesized that osteochondral allograft transplantation after failed cartilage repair would result in low failure rates and improved function and that improved graft incorporation on postoperative magnetic resonance imaging (MRI) would correlate with a superior clinical outcome.

Methods: A retrospective review of prospectively collected data was used to identify 43 patients treated with fresh osteochondral allograft transplantation after a previous cartilage repair surgical procedure and having a minimum follow-up of 2 years. Clinical outcomes were evaluated using the Short Form-36 (SF-36) score, International Knee Documentation Committee (IKDC) Subjective Knee Score, Marx Activity Scale, Knee Outcome Survey-Activities of Daily Living (KOS-ADL) Questionnaire, Cincinnati Sports Activity Score, and Cincinnati Overall Symptom Assessment. Postoperative MRI scans were obtained at a mean time of 19.7 months and were independently reviewed by a musculoskeletal radiologist using the Osteochondral Allograft MRI Scoring System (OCAMRISS).

Results: At a mean 3.5-year follow-up after osteochondral allograft transplantation, significant improvements ($p < 0.05$) in SF-36 Physical Function, SF-36 Pain, KOS-ADL, IKDC Subjective Knee Score, and Cincinnati Overall Symptom Assessment were seen. Over 90% of grafts remained in situ at the time of the latest follow-up, although 17 knees (40%) underwent reoperation, the majority for arthroscopic debridement or manipulation for stiffness. Body mass index (BMI) of >30 kg/m^2 was associated with worse clinical outcomes. The mean total OCAMRISS score demonstrated poorer allograft integration in patients with graft failure, but the total score did not meaningfully correlate with clinical outcome scores. However, better individual articular cartilage appearance and osseous integration subscores were associated with better clinical outcome scores.

Conclusions: Significant improvements in pain and function were seen following fresh osteochondral allograft transplantation after failed cartilage repair, with an overall graft survival rate of >90%. Patients with greater bone and cartilage incorporation on MRI had superior clinical outcomes, although persistent osseous edema was frequently seen. We concluded that osteochondral allograft transplantation is an effective salvage treatment after failed cartilage repair and recommend further evaluation of techniques to optimize graft integration.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

Advancements in cartilage repair have led to a variety of options to treat full-thickness articular cartilage lesions, such as marrow stimulation, autologous chondrocyte implantation, osteochondral autograft transfer, and fresh osteochondral allograft transplantation[1-3]. Despite evolution of techniques, longer-term follow-up of cartilage repair procedures

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reveals deterioration of clinical outcomes and failure rates approaching 25%[4,5].

Disruption of the subchondral plate, cystic osseous changes, and enlarged defect size are common scenarios presenting after a failed cartilage repair surgical procedure[4,6,7]. Although the ideal salvage cartilage repair procedure remains debated, fresh osteochondral allograft transplantation has emerged as an appealing treatment option given the ability to treat large lesions, to address bone loss, and to be performed in a single stage. Previous studies evaluating autologous chondrocyte implantation or osteochondral allograft transplantation in the revision setting have demonstrated higher reoperation and failure rates, with a variable correlation of clinical outcomes with postoperative imaging[8-10].

The purpose of this study was to evaluate osteochondral allograft transplantation when performed after failed cartilage repair, as measured by graft failure and patient-reported outcomes. In addition, we sought to describe graft incorporation using a novel magnetic resonance imaging (MRI) scoring system specifically designed for osteochondral allograft transplantation and to correlate graft integration with clinical outcomes[11,12]. We hypothesized that osteochondral allograft

TABLE I Components of the OCAMRISS*

Features	MRI Feature	MRI Score
Cartilage features	1. Cartilage signal of graft	0: Normal 1: Altered intensity (hypointense or hyperintense, but not fluid) 2: Fluid signal intensity on all sequences
	2. Cartilage "fill" of graft (percentage of volume)	0: 76% to 100% 1: 51% to 75%, or >100% 2: <50%
	3. Cartilage edge integration at host-graft junction	0: No discernible boundary 1: Discernible boundary 2: Discernible fissure >1 mm
	4. Cartilage surface congruity of graft and host-graft junction	0: Flush 1: <50% offset of host cartilage 2: >50% offset of host cartilage
	5. Calcified cartilage integrity of graft	0: Intact, thin, and smooth 1: Altered (disrupted, thickened, or blurred)
Bone features	6. Subchondral bone plate congruity of graft and host-graft junction	0: Intact and flush 1: Disrupted or not flush by >1 subchondral thickness
	7. Subchondral bone marrow signal intensity of graft relative to epiphyseal bone	0: Normal 1: Abnormal (bone marrow edema pattern or hypointensity on all sequences)
	8. Osseous integration at host-graft junction	0: Crossing trabeculae 1: Discernible cleft
	9. Presence of cystic changes of graft and host-graft junction	0: Absent 1: Present
Ancillary features	10. Opposing cartilage	0: Normal 1: Abnormal
	11. Meniscal tears	0: Absent 1: Present
	12. Synovitis	0: Absent 1: Present
	13. Fat pad scarring	0: Absent 1: Present

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transplantation in the revision setting would result in low failure rates and improved postoperative function and that greater MRI graft incorporation would be associated with superior clinical outcome.

Materials and Methods

This study was performed as a retrospective review of a prospective registry of all patients treated for knee articular cartilage lesions at an academic medical center. Institutional review board approval was obtained for analysis, and all patients provided informed consent. Inclusion criteria included consecutive patients treated with fresh osteochondral allograft transplantation in the distal part of the femur after a failed previous cartilage repair surgical procedure and a minimum follow-up of 2 years.

On the day of the surgical procedure, patient demographic information, medical history, and intraoperative data were recorded. Preoperative and postoperative evaluation included the physical function, pain, and general health subscales of the Short Form-36 (SF-36), International Knee Documentation Committee (IKDC) Subjective Knee Score, Marx Activity Scale, Knee Outcome Survey-Activities of Daily Living (KOS-ADL) Questionnaire, and the Sports Activity and Overall Symptom Assessment subscores of the Cincinnati Knee Rating System. The most recent scores were used for analysis and medical records were also individually reviewed at the time of the latest follow-up. Failure was defined as any procedure that required removal of the osteochondral allograft.

In our practice, postoperative MRI scans are made to evaluate allograft integration at 6 months, 1 year, and 2 years postoperatively; for consistency, the MRI closest to 1 year postoperatively was chosen for this study. MRI scans were performed on a 1.5-T or 3.0-T system with sagittal inversion recovery and axial, sagittal, and coronal moderate-echo-time fast-spin-echo proton-density-weighted images. All MRI scans were scored by a fellowship-trained musculoskeletal radiologist blinded to the patient's medical history using the Osteochondral Allograft MRI Scoring System (OCAMRISS) (Table I)[11,12]. OCAMRISS is specifically developed to evaluate osteochondral allograft incorporation and places emphasis on features of articular cartilage and subchondral bone at the repair site; a lower total score indicates better incorporation of the graft, with possible scores ranging from 0 to 17 points. This scoring system was originally validated with histopathologic and micro-computed tomography (micro-CT) and was shown to have high interrater reliability[12].

Surgical Technique

Diagnostic arthroscopy was performed on all patients at the time of osteochondral allograft transplantation to confirm the size and depth of the lesion, as well as to address any concurrent intra-articular pathology. A medial or lateral parapatellar arthrotomy was then made, depending on the location of the lesion. The articular cartilage defect was sized and was reamed to a depth of approximately 8 to 10 mm. Fresh, cold-stored distal femoral allografts were obtained after screening and processing according to the American Association of Tissue Banks standards[13]. Grafts were transplanted between 15 and 30 days from harvest, and the donor site was selected to match the radius of the curvature to the defect. A cylindrical plug of matching diameter and depth was creating using a coring reamer. The osteochondral allograft was then irrigated using pulsatile lavage and was gently press-fit into the defect without supplemental internal fixation or biological augmentation[14,15].

Patients were typically discharged on the same day as the surgical procedure and were initially restricted to toe-touch weight-bearing. A range of motion from 0° to 90° was then allowed within the first week postoperatively. A gradual transition to weight-bearing as tolerated was allowed after 4 weeks. A return to higher-level activities and athletics was

TABLE II Patient Demographic and Knee-Specific Data (N = 43)

Patient characteristics	
Age* *(yr)*	31.1 (14.6 to 61.9)
Sex†	
Male	29
Female	14
BMI* *(kg/m²)*	25.4 (18.2 to 39.1)
No. of previous surgical procedures*	2.51 (1 to 10)
Lesion location†	
Medial femoral condyle	22
Lateral femoral condyle	18
Trochlea	2
Combined (medial femoral condyle and trochlea)	1
Lesion characteristics*	
Chondral defect area *(cm²)*	4.2 (1.2 to 7.1)
No. of allograft dowels used	1.51 (1 to 3)
Diameter of osteochondral allograft used *(mm)*	23.1 (15 to 30)
Type of previous cartilage repair procedure†	
Subchondral marrow stimulation	21
Surgical treatment of osteochondritis dissecans (fixation or drilling)	7
Osteochondral allograft transplantation	4
Autologous chondrocyte transplantation	4
Synthetic osteochondral scaffold (OBI TruFit; Smith & Nephew)	3
Osteochondral autograft transfer	1
Unspecified cartilage repair procedure†	3

*The values are given as the mean with the range in parentheses. †The values are given as the number of patients. ‡This procedure is listed when the patient reported a history of a cartilage repair procedure but was unable to recall the specific type of procedure performed.

initiated on an individual patient basis, typically starting with a running program at 6 months. Sports-specific training was then progressed, thereafter depending on the return of lower-extremity strength, muscle endurance, proprioception, and overall limb function.

Statistical Analysis

The paired t test was used to compare preoperative and postoperative clinical outcome scores. Independent 2-sample t tests were used to compare postoperative outcomes between binary patient-specific factors (body mass index [BMI] of ≥30 kg/m^2 or <30 kg/m^2) as well as OCAMRISS subscore features: cartilage signal (normal or altered intensity), cartilage fill (<50% or ≥50%), osseous integration (crossing trabeculae or discernible cleft), bone marrow signal (normal or abnormal), and cystic changes (absent or present). The comparisons between BMI (≥30 kg/m^2 or <30 kg/m^2) and OCAMRISS subscore were evaluated using the chi-square or Fisher exact test. Significance was set at $p < 0.05$.

Results

A total of 43 patients treated by 3 surgeons over a 9-year period (2007 to 2015) were identified. Patient demographic and knee-specific data are provided in Table II. One or more concurrent procedures were performed in 19 patients, including an arthroscopic meniscal surgical procedure (6 patients), an osteochondral allograft at a separate location (6 patients), a meniscal transplant (3 patients), a revision anterior cruciate ligament reconstruction (2 patients), and a femoral or tibial osteotomy (3 patients).

The mean postoperative follow-up was 3.5 years (range, 2.0 to 7.5 years). During this interval, 17 knees (40%) required at least 1 further surgical procedure at a median of 15.4 months (range, 4.7 weeks to 4.1 years) after the osteochondral allograft transplantation; 4 patients required 2 subsequent surgical procedures. These reoperations included arthroscopic debridement for loose bodies or chondroplasty (9 patients), manipulation under anesthesia for stiffness (3 patients), and removal of the implant for failure (4 patients). No superficial or deep postoperative infections were observed.

Four knees (9%) over this interval were classified as undergoing failed treatment, in which the osteochondral allograft had to be removed and revised to a second fresh osteochondral allograft transplant (1 patient), arthroscopic chondroplasty followed by revision osteochondral allograft transplantation with concurrent meniscal allograft (1 patient), unicondylar knee replacement (1 patient), or total knee replacement (1 patient). The mean time to failure was 18.5 months. Of note, the 2 patients who were converted to knee arthroplasty were 46.6 and 61.9 years of age at the time of osteochondral allograft transplantation.

Thirty-six patients (84%) had clinical outcome scores available for review at the time of the latest follow-up. The preoperative and postoperative comparisons of the scores demonstrated significant improvements in SF-36 Physical Function (mean [and standard deviation], 60.8 ± 18.8 points [95% confidence interval (CI), 53.7 to 66.3 points] preoperatively compared with 84.3 ± 14.9 points [95% CI, 79.3 to 89.2 points] postoperatively; $p < 0.01$), SF-36 Pain

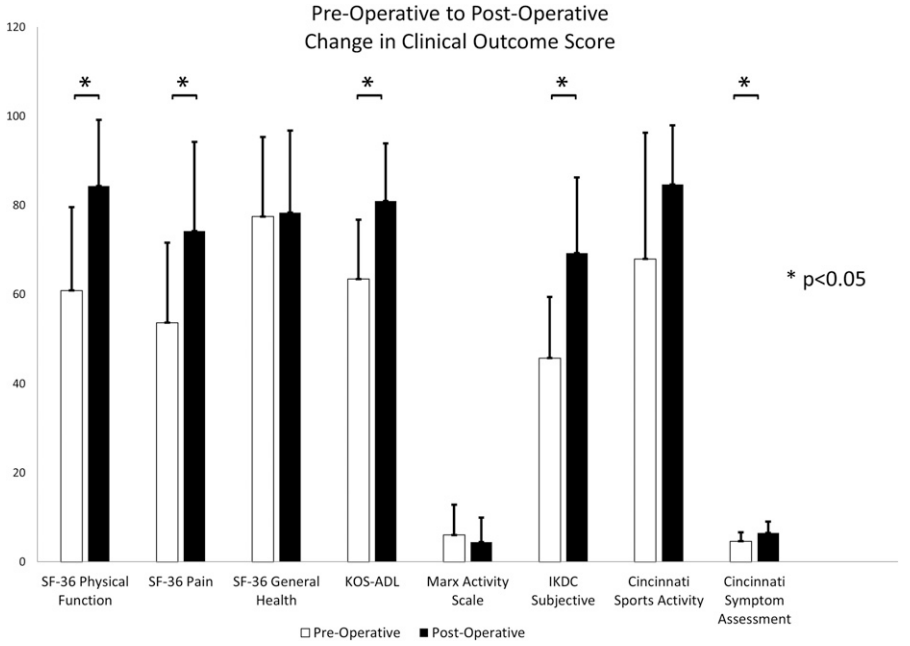

Fig. 1

Bar graph showing the comparison of preoperative and postoperative patient-reported outcome scores. The error bars indicate the standard deviation. The asterisks indicate significance at $p < 0.05$.

TABLE III Correlation Between Total OCAMRISS Score and Change in Outcome Score from Preoperatively to Postoperatively

	Pearson Correlation Coefficient	P Value
SF-36 General Health subscale		
Change score	−0.04	0.827
Postoperative score	−0.17	0.338
SF-36 Pain subscale		
Change score	−0.19	0.323
Postoperative score	−0.24	0.180
SF-36 Physical Function subscale		
Change score	−0.15	0.442
Postoperative score	−0.36	0.035*
Knee Outcome Survey-Activities of Daily Living		
Change score	−0.16	0.488
Postoperative score	−0.32	0.076
IKDC Subjective Knee Score		
Change score	−0.16	0.455
Postoperative score	−0.26	0.144
Marx Activity Scale		
Change score	0.05	0.816
Postoperative score	0.15	0.406
Cincinnati Sports Activity Subscale		
Change score	−0.09	0.776
Postoperative score	−0.16	0.478
Cincinnati Overall Symptom Assessment Subscale		
Change score	−0.07	0.775
Postoperative score	0.09	0.672

*Significant.

(53.6 ± 18.0 points [95% CI, 47.8 to 59.4 points] compared with 74.2 ± 20.0 points [95% CI, 67.8 to 80.7 points]; $p < 0.01$), KOS-ADL (63.4 ± 13.4 points [95% CI, 59.1 to 67.7 points] compared with 80.9 ± 13.0 points [95% CI, 76.8 to 85.1 points]; $p < 0.01$), IKDC Subjective Knee Score (45.7 ± 13.7 points [95% CI, 41.3 to 50.1 points] compared with 69.2 ± 17.0 points [95% CI, 63.8 to 74.7 points]; $p < 0.01$), and Cincinnati Overall Symptom Assessment (4.6 ± 2.0 points [95% CI, 4.0 to 5.3 points] compared with 6.5 ± 2.5 points [95% CI, 5.7 to 7.3 points]; $p = 0.014$) (Fig. 1). There were no significant differences observed for the mean scores for SF-36 General Health (77.4 ± 17.9 points [95% CI, 71.7 to 83.2 points] compared with 78.3 ± 18.5 points [95% CI, 72.3 to 84.2 points]; $p = 0.36$), Marx Activity Scale (6.0 ± 6.8 points [95% CI, 3.9 to 8.2 points] compared with 4.4 ± 5.5 points [95% CI, 2.6 to 6.2 points]; $p = 0.06$), or Cincinnati Sports Activity Score (67.9 ± 28.4 points [95% CI, 58.8 to 77.1 points] compared with 84.6 ± 13.3 points [95% CI, 80.3 to 88.9 points]; $p = 0.19$).

Patients with a BMI of ≥30 kg/m^2 ($n = 6$) had lower mean postoperative values for the KOS-ADL (67.0 compared with 82.7 points; $p = 0.045$), Marx Activity Scale (1.6 compared with 4.9 points; $p = 0.014$), IKDC Subjective Knee Score (54.0 compared with 71.3 points; $p = 0.037$), and Cincinnati Sports Activity Score (60.0 compared with 88.3 points; $p = 0.007$) and less interval score improvement in the KOS-ADL (1.9 compared with 18.4 points; $p = 0.03$), IKDC Subjective Knee Score (7.4 compared with 25.9 points; $p = 0.007$), and Cincinnati Overall Symptom Assessment (−1.47 compared with 2.29 points; $p = 0.048$) than patients with a BMI of <30 kg/m^2 ($n = 30$). Although not significant,

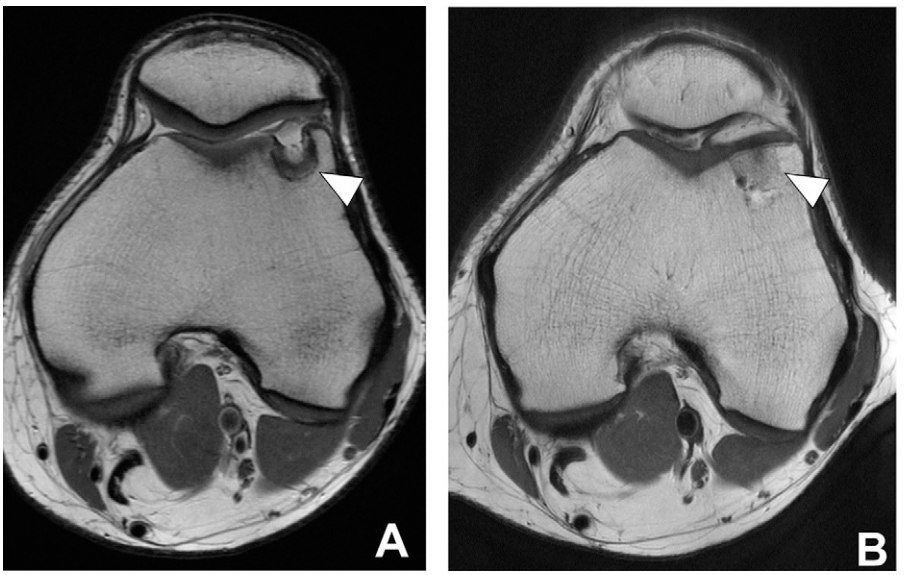

Fig. 2

Figs. 2-A and 2-B Axial fast-spin-echo MRI scans of the left knee in an 18-year-old man. **Fig. 2-A** MRI demonstrating the preoperative osteochondral defect (arrowhead) over the lateral trochlea after a previously placed synthetic graft. **Fig. 2-B** MRI performed approximately 20 months following salvage osteochondral allograft transplantation demonstrating good fill of the defect (arrowhead), progressive osseous incorporation, and intact articular surface with normal signal without clefts.

patients with a BMI of ≥30 kg/m^2 also had SF-36 Physical Function, Pain, and General Health scores that were lower by >0.4 standard deviation.

Imaging

Thirty patients who received 40 fresh osteochondral allograft implants had postoperative MRI scans for review, obtained

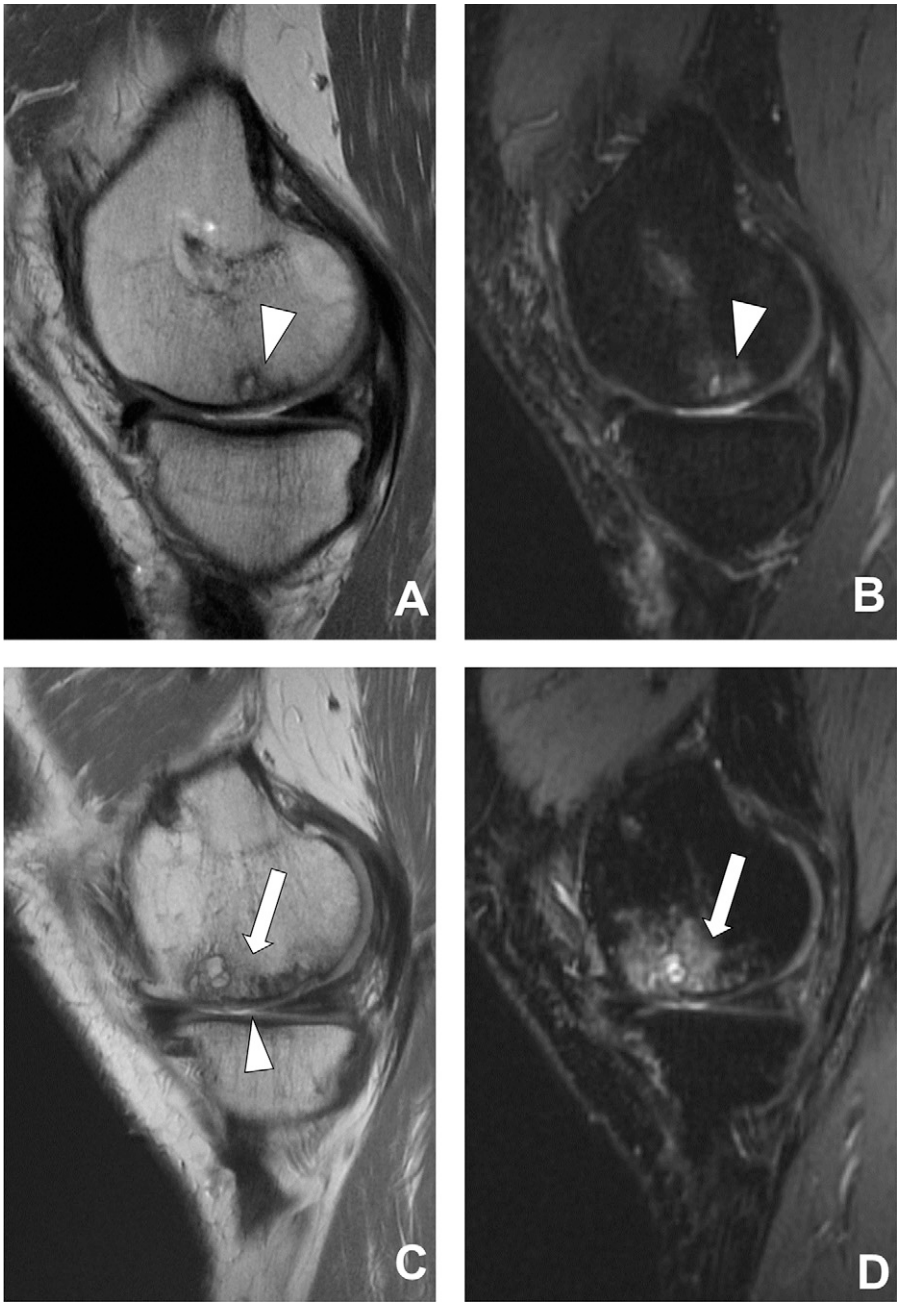

Fig. 3

Figs. 3-A through 3-D Images of the right knee in a 44-year-old man demonstrating articular cartilage loss in the medial femoral condyle after failed subchondral marrow stimulation. **Fig. 3-A** Sagittal proton density image. Subchondral cystic resorption, osseous edema, and fissures extending past the tidemark are seen (arrowhead). **Fig. 3-B** Inversion recovery image. Subchondral cystic resorption, osseous edema, and fissures extending past the tidemark are seen (arrowhead). **Fig. 3-C** Sagittal proton density image obtained 30 months after fresh osteochondral allograft transplantation demonstrating an abnormal bone marrow edema pattern, cystic changes at the graft-host junction, and absence of crossing trabeculae (arrow). Articular cartilage thinning is noted with altered signal and a discernable fissure to adjacent cartilage (arrowhead). **Fig. 3-D** Inversion recovery image obtained 30 months after fresh osteochondral allograft transplantation demonstrating an abnormal bone marrow edema pattern, cystic changes at the graft-host junction, and absence of crossing trabeculae (arrow).

at a mean postoperative time of 19.7 months (median, 13.7 months; range, 7.2 to 46.3 months). The mean total OCAMRISS score for all patients was 10.1 ± 3.3 points; this value was greater in patients who had failure of the osteochondral allograft transplantation (12.6 ± 1.7 points) compared with those who did not have failure of the transplantation (9.6 ± 3.3 points) ($p < 0.01$). The total OCAMRISS score only correlated weakly with the postoperative SF-36 Physical Function score (Pearson correlation coefficient, −0.36; $p = 0.035$) but not with other clinical outcomes (Table III). No differences in the total OCAMRISS score were seen when comparing early MRI (<2 years) compared with late MRI (>2 years).

Specific features of the OCAMRISS score were also individually analyzed. Overall, grafts demonstrated satisfactory preservation of the articular contour, as 85% of grafts had ≥50% cartilage fill by volume and 90% of grafts had a cartilage surface that was flush or offset by <50% of its thickness from the host cartilage (Fig. 2). On postoperative MRI, 42.5% of grafts had a normal-appearing cartilage signal. However, signs of incomplete osseous integration were still seen in some grafts, as trabeculae crossing the graft-host junction was only visualized in 50% of grafts. Furthermore, 92.5% of grafts demonstrated abnormal bone marrow edema patterns, and 52.5% of grafts had cystic changes at the base (Fig. 3). The complete OCAMRISS scoring data for all patients in this study are provided in the Appendix.

Better articular cartilage appearance on postoperative MRI was associated with improved clinical outcome scores (Fig. 4). Patients with a normal cartilage signal had higher SF-36 Physical Function (normal, 89.3 points, compared with abnormal, 80.3 points; $p = 0.074$), SF-36 Pain (81.6 points compared with 68.2 points; $p = 0.053$), KOS-ADL (86.7 compared with 75.1 points; $p = 0.007$), and IKDC Subjective Knee Score (78.2 compared with 58.5 points; $p = 0.002$), compared with patients with abnormal (hyperintense or hypointense) articular cartilage signal. In addition, improved osseous integration on postoperative MRI was associated with better clinical outcome scores (Fig. 5). Patients with cystic changes at the graft-host junction had worse outcomes than those without (Fig. 6), as assessed by the Marx Activity Scale (1.3 points for cystic changes compared with 5.8 points for no cystic changes; $p = 0.008$), IKDC Subjective Knee Score (61.1 compared with 74.3 points; $p = 0.049$), and Cincinnati Sports Activity Score (76.0 compared with 90.4 points; $p = 0.022$). Furthermore, patients with trabeculae crossing the graft-host junction had higher SF-36 Physical Function scores (89.4 compared with 78.3 points; $p = 0.045$) and KOS-ADL scores (84.0 compared with 76.0 points; $p = 0.08$) than patients without trabeculae crossing the graft-host junction. No differences in outcomes were observed when comparing the quantity of cartilage fill, the presence of abnormal bone marrow signal, or the presence of synovitis on postoperative MRI.

Patients with a BMI of <30 kg/m^2 more frequently had a normal cartilage signal (50.0% compared with 0.0%; $p = 0.029$) and ≥50% cartilage fill (91.7% compared with 50.0%; $p = 0.029$), and they had a lower mean total OCAMRISS score (9.5 ± 3.1 compared with 13.0 ± 2.1 points; $p = 0.013$) compared with patients with a BMI of ≥30 kg/m^2.

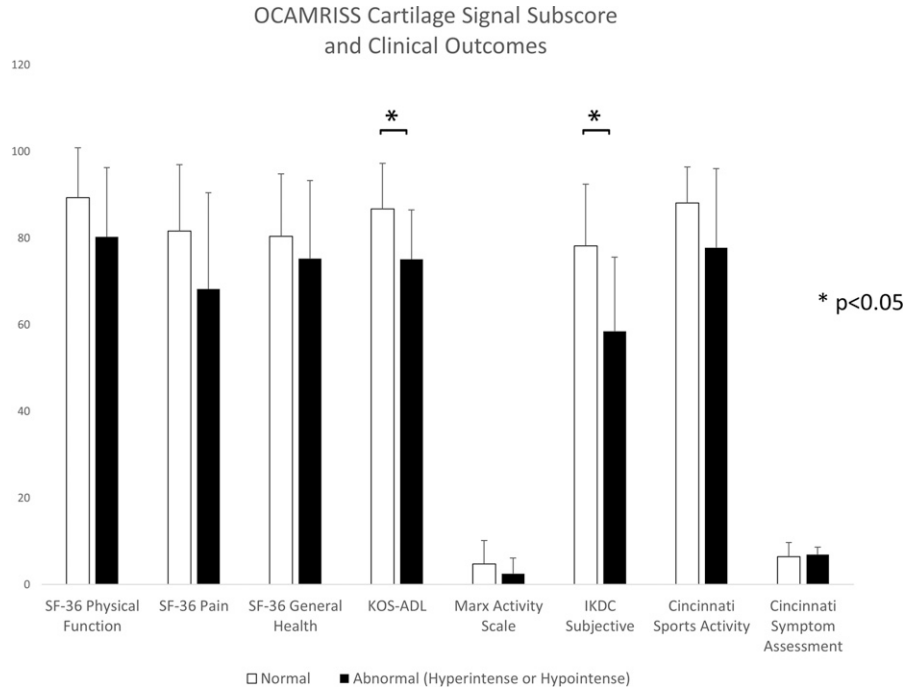

Fig. 4

Bar graph showing the comparison of postoperative patient-reported outcomes by OCAMRISS cartilage signal subscore. The error bars indicate the standard deviation. The asterisks indicate significance at $p < 0.05$.

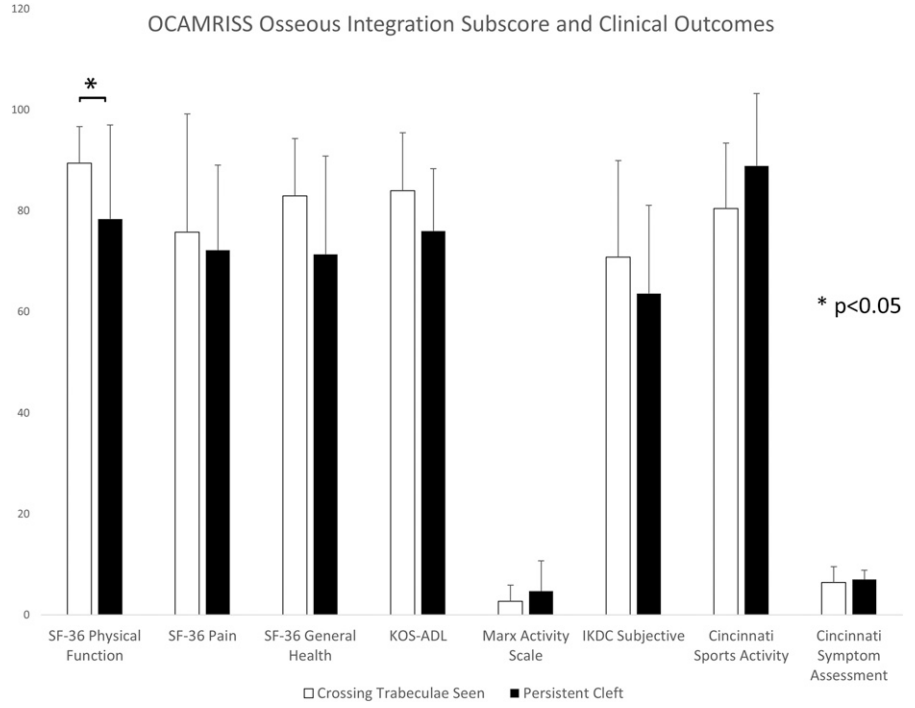

Fig. 5

Bar graph showing the comparison of postoperative patient-reported outcomes by OCAMRISS osseous integration. The error bars indicate the standard deviation. The asterisk indicates significance at $p < 0.05$.

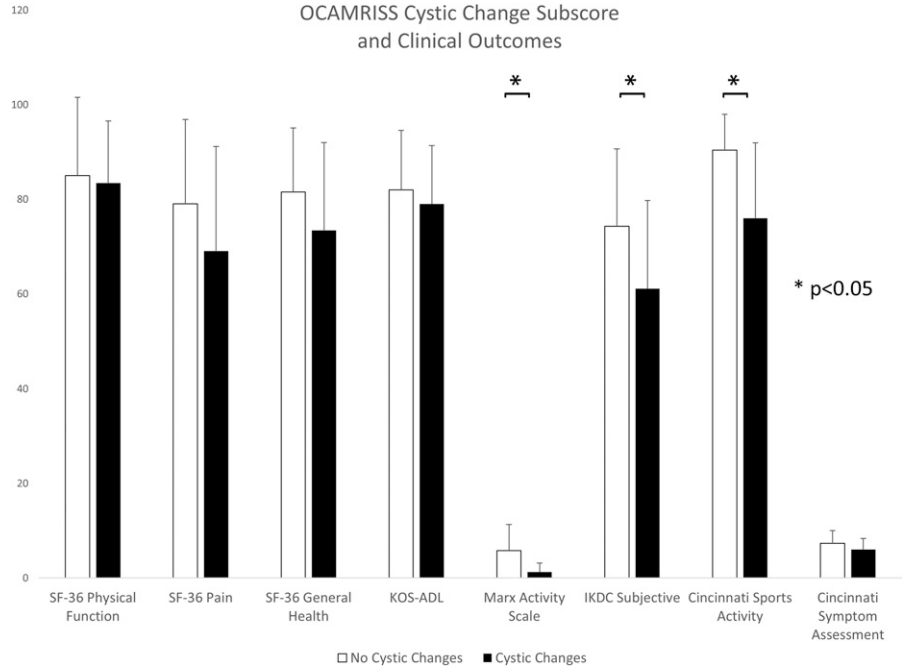

Fig. 6

Bar graph showing the comparison of postoperative patient-reported outcomes by OCAMRISS cystic changes. The error bars indicate the standard deviation. The asterisks indicate significance at $p < 0.05$.

Discussion

There are distinct limitations to current cartilage repair techniques, suggesting the need to identify effective salvage procedures[16-18]. Subchondral marrow stimulation, historically the most common procedure, leads to formation of fibrocartilage with poor wear characteristics and

reoperation rates estimated at 25% to 39%[19-24]. Autologous chondrocyte implantation performed after previous cartilage procedures[10] results in worse clinical outcomes and failure rates up to 3 times higher[7,9] than in the primary setting[25,26]. Although debate remains with regard to the ideal salvage procedure[4], the advantages of osteochondral allograft transplantation include the ability to treat large defects, address subchondral bone damage, restore the hyaline ultrastructure, and be performed in a single stage. Osteochondral allograft transplantation has been shown to improve postoperative pain and function, with the potential added benefit of faster recovery[2,20,27-33].

The principal finding of this study is the improvement in clinical outcomes after fresh osteochondral allograft transplantation following failed cartilage repair, with the vast majority of grafts surviving at the intermediate-term follow-up. The failure rate of 9.3% and the reoperation rate of 39.5% are clinically meaningful and consistent with prior publications with this technique. Unique to this study was the use of postoperative MRI to evaluate graft incorporation: patients with improved osseous and cartilaginous appearance had superior clinical outcomes. However, a large proportion of patients demonstrated persistent signs of incomplete osseous healing.

In this study, fresh osteochondral allograft transplantation performed after failed cartilage repair led to significant improvements in pain and function. However, at a mean postoperative follow-up of 3.5 years, we found a reoperation rate of 39.5% and graft survival of 90.7%. Other authors have estimated survivorship for fresh osteochondral allograft transplantation as 71% to 89% at 10 years[3,34-37] and have reported similarly high reoperation rates between 37% and 53%, the majority as arthroscopic debridement[38,39]. Similar to previous reports, we found that patients with a BMI of ≥30 kg/m^2 had lower total postoperative clinical scores, less interval improvement, and poorer MRI outcomes after cartilage repair[8,23,38,39].

Interpreting differences between primary and revision osteochondral allograft transplantation remains difficult as many studies include both primary and revision procedures. Gracitelli et al. found no differences in survivorship or clinical outcomes when comparing patients undergoing primary osteochondral allograft transplantation with those undergoing transplantation after failed marrow stimulation, although patients with prior marrow stimulation had higher reoperation rates[26]. In knees undergoing osteochondral allograft transplantation after failed cartilage repair, the authors reported a 41.4% reoperation rate and an 18.9% failure rate[8]. Horton et al. similarly showed a 67% reoperation rate and a 39% failure rate at 10 years for osteochondral allograft transplantation in the revision setting, inferior to outcomes in the primary setting[40].

A unique finding in our study was the association of graft integration on MRI with a superior clinical outcome. The relatively novel OCAMRISS scoring system used in this study, developed for in vivo evaluation of osteochondral allografts[11], places emphasis on the subchondral bone[12]. Although we did not find the total OCAMRISS score to correlate with the clinical outcome, analysis of individual bone and cartilage subscales of the OCAMRISS revealed that knees without cystic subchondral change, those that had had trabeculae crossing the defect site, and those that had normal articular cartilage signal had better function. Interestingly, Meric et al. correlated better clinical outcomes with the total OCAMRISS score but not with subchondral bone features, as seen in the present study[12]. This suggests that MRI outcomes specific for osteochondral allograft transplantation may reveal an association between graft integration and clinical outcome. Of note, few studies evaluating osteochondral allograft transplantation have utilized postoperative MRI scans; most have presented clinical outcomes only[41]. Williams et al. reported that 95% of osteochondral allograft grafts had preserved cartilage thickness and 74% had osseous incorporation on postoperative MRI, which correlated with better SF-36 scores[42]. In our series, 92.5% of patients had persistent marrow edema and only 50% demonstrated crossing trabeculae on postoperative MRI. Although some authors have shown better repair-tissue fill associated with better clinical outcomes[23], this is not universally reported and may depend on the lesion location and type of procedure performed[43-46]. Additionally, biological augmentation of osteochondral allograft transplantation may also improve graft incorporation[47].

The strengths of this study include prospective collection of patient-reported outcome data and both duration of follow-up and follow-up rate. In addition, the inclusion of postoperative MRI scans, rarely reported in other studies of osteochondral allograft transplantation, allows detailed evaluation of graft integration. An independent musculoskeletal radiologist, blinded to clinical outcome, evaluated all MRI scans to minimize bias and used a scoring system specific for osteochondral allograft transplantation. The outcome instruments in this study were selected for their reliability, validity, and responsiveness for assessing different aspects of knee health[48-50]. The SF-36 is a generic health questionnaire, with specific dimensions chosen to measure effects of knee health on function. The KOS-ADL and Cincinnati Knee Rating System are validated outcomes to measure physical limitations of the knee during activities of daily living[51,52]. The IKDC Subjective Knee Score and the Marx Activity Scale both are sensitive to the presence of articular cartilage lesions[53].

The limitations of this study included the retrospective design and lack of a comparison group. In addition, the cohort included a relatively heterogenous population with respect to previous operations and concomitant procedures. However, we believe that these results are still meaningful as this represents the demographic group who have undergone a failed cartilage operation and procedures commonly performed in the revision setting. Previous series of osteochondral allograft transplantation have shown similarly high rates of concomitant procedures[26,35,36,38,54]. We defined

failure as graft removal, in accordance with other published studies, given the lack of a defined minimum clinically important difference for this procedure. In addition, postoperative MRI scans were obtained in 70% of patients in this study; however, no differences in demographics or clinical scores were seen between patients who had MRI follow-up and those who did not.

In conclusion, we have reported significant improvements in patient-reported outcomes after fresh osteochondral allograft transplantation in the setting of failed cartilage repair, with the majority of grafts surviving at the time of the intermediate-term follow-up. Postoperative MRI scans reveal that patients with better bone and cartilage incorporation had better clinical outcomes, although many patients demonstrate signs of incomplete healing. We concluded that osteochondral allograft transplantation is an effective salvage option after failed cartilage repair and recommend further evaluation of techniques to optimize graft integration.

Appendix

eA A table showing the total OCAMRISS scoring for patients in this study is available with the online version of this article as a data supplement at jbjs.org (http://links.lww.com/JBJS/E950). ■

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Update

This article was updated on December 4, 2018, because of previous errors. On pages 1949 and 1958, in the byline, the second author was incorrectly listed as "Dean X. Wang, MD," which was then abbreviated to "D.X. Wang" in the ORCID iD list. The author's name is now listed as "Dean Wang, MD" in the byline and abbreviated to "D. Wang" in the ORCID iD list. Additionally, on page 1958, in the ORCID iD list, the ORCID iD for Dr. Scott A. Rodeo was incorrectly listed as "0000-0003-2991-7173." Dr. Rodeo's ORCID iD is now listed as "0000-0002-0745-9880."

An erratum has been published: J Bone Joint Surg Am. 2019 Jan 16;101(2):e9.