The Influence of Full-Thickness Chondral Defects on Outcomes Following Meniscal Allograft Transplantation: A Comparative Study

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Purpose: To compare a series of patients who underwent meniscus allograft transplantation (MAT) with full-thickness chondral defects (FTD) with those with no chondral defect (ND) with regard to the following: change in patient-reported outcomes (PROs) from baseline to 2-year follow-up and baseline to the final follow-up (including comparisons to minimal clinically important differences), complications and complication rates, reoperations and reoperation rates/timing, and failures and time to failure (revision MAT or conversion to total knee arthroplasty). **Methods:** Patients who underwent isolated medial or lateral MAT between September 1997 and March 2013 with a minimum of 2 years of follow-up were retrospectively identified and split into 2 groups based on the presence or absence of FTD (femoral condyle or tibial plateau) identified intraoperatively after debridement to allow for a better understanding of the lesion characteristics (when applicable): ND (Outerbridge grade 0/I) or FTD (Outerbridge grade IV). Patients with osteochondritis dissecans were eligible for inclusion, as were those with isolated single lesions, multiple lesions, or bipolar lesions. Those with a moderate Outerbridge grade (II and III)—whether treated or neglected—were excluded given the poorer reliability of grading intermediate lesions. Indications for MAT included those patients with subjective complaints (persistent joint-line pain) and objective findings (previous meniscectomy or nonviable meniscus state with pain localized to the affected compartment) of functional meniscal deficiency. All lateral MAT patients used a bridge-in-slot surgical technique, as did most medial MAT patients (few patients with earlier surgical dates received a keyhole technique). All FTD were treated concurrently at the time of index MAT with cartilage restoration procedures (microfracture, autologous chondrocyte implantation, DeNovo particulate cartilage grafting, or osteochondral auto/allografting). Reoperations, failures (revision MAT or conversion to arthroplasty), and PRO deltas were reported comparing baseline to 2-year follow-up and baseline to the final follow-up. Intergroup comparisons were made using Bonferroni-adjusted independent sample *t*-tests for continuous variables and χ-square for categorical variables. **Results:** A total of 91 patients (22 ND and 69 FTD) were identified and followed for a mean 4.48 $\pm$ 2.63 and 3.84 $\pm$ 2.47 years, respectively. There were no significant between-group differences in age, body mass index, or number of prior surgeries. The mean chondral lesion size in the FTD group was 4.43 $\pm$ 2.5 cm^2. Concomitant anterior cruciate ligament reconstruction was performed significantly more in ND-group patients than FTD-group patients (8 [38.1%] vs 8 [11.8%], $P = .004$). There were no differences between ND-group and

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FTD-group patients in concomitant realignment procedures performed (2 [9.1%] vs 7 [10.1%], $P = .986$), or prior ligament reconstruction (9 [40.9%] vs 18 [26.1%], $P = .111$) or realignment procedure (0 [0%] vs 0 [0%]). FTD-group patients underwent concomitant osteochondral allograft (69.6%), autologous chondrocyte implantation (18.8%), microfracture (13.0%), osteochondral autograft (4.3%), or DeNovo juvenile particulate cartilage implantation (1.4%). A comparison of the patient groups found no statistically significant differences in PROs preoperatively ($P > .003$ for all). Intergroup comparisons of both the 2-year and final follow-up delta PRO scores showed no statistically ($P > .003$ for all) or clinically (number of PROs meeting minimal clinically important differences) significant differences. One complication occurred (fractured hardware) in the FTD-group patients (1.3%). There were no differences in the number of subsequent surgeries (revision MAT: ND, 2 (10.0%) vs FTD, 8 (12.9%); $P = .845$) or failures (conversion to total knee arthroplasty: ND, 1 (5.0%) vs FTD, 2 (3.3%); $P = .646$). **Conclusions:** When comparing a patient series with FTD who underwent MAT with a patient series with ND, there were no differences in the change in individual PROs from preoperative to the final follow-up. Similarly, there were no differences in complications or failure between those with ND or FTD diagnosed intraoperatively. The results of the current study suggest that chondral damage identified and treated by cartilage restoration means at the time of MAT may not affect the clinical outcomes of MAT. **Level of Evidence:** Level III, retrospective comparative study.

The meniscus plays a critical role in the tibiofemoral joint with regard to load transmission, stability, lubrication, proprioception, and shock absorption.[1-3] It also plays a critical role in the prevention of osteoarthritis, because meniscectomy has been shown to lead to a 4- to 5-fold increased rate of osteoarthritis and a 132-fold increased risk of early total knee arthroplasty (TKA) when compared with the unoperated knee in the same patients.[4] Thus, the treatment of meniscal injury has shifted from meniscectomy[5] to repair and preservation of viable and functional meniscal tissue when possible.[6] In recent decades, meniscus allograft transplantation (MAT) has emerged as a viable option to reduce pain in symptomatic patients with a history of total or subtotal meniscectomy.[5]

Traditionally, the indications for MAT included patients under 50 years of age with persistent pain in a meniscectomized compartment, but without radiographic evidence of diffuse arthritic changes or joint-space narrowing, inflammatory arthritis, marked obesity, ligamentous insufficiency, or malalignment.[7-9] Multiple studies have shown improvements in pain and functional outcomes after MAT,[5,6,10-15] with age, number of prior surgeries, and preoperative pain being the established predictors of its success.[10,12] However, the impact of articular cartilage damage at the time of surgery—a common concomitant finding in the patient with meniscal injury or deficiency and a relative contraindication to the MAT procedure unless addressed at the time of surgery or in a staged fashion—remains inconclusive.[10,16]

The primary outcome measured and compared between patients with full-thickness chondral defects (FTD) and those with no chondral defects (ND) was the change in patient-reported outcomes (PROs) comparing baseline to 2-year follow-up and baseline to the final follow-up. Our secondary outcome was the evaluation of the impact of a treated FTD on complications, reoperations, and failures (revision MAT or conversion to arthroplasty) after MAT as compared with patients with ND who underwent MAT. The purpose of this study was to compare a series of patients who underwent MAT with FTD with those with ND with regard to the following: change in PROs from baseline to 2-year follow-up and baseline to the final follow-up (including comparisons to minimal clinically important differences [MCID]), complications and complication rates, reoperations and reoperation rates/timing, failures and time to failure (revision MAT or conversion to TKA). Our primary hypothesis was that the presence of chondral defect at the time of surgery would not affect the degree of improvement in PROs between baseline and long-term follow-up if treated concurrently with a cartilage restoration procedure. Secondarily, we similarly hypothesized that there would be no difference between patients with ND and those with FTD in terms of reoperations or failures after MAT at the final follow-up.

Methods

Following Institutional Review Board (IRB) approval, all patients who underwent medial or lateral meniscal allograft transplantation by a single surgeon (B.J.C.) between September 1997 and March 2013 with a minimum 2-year clinical follow-up were retrospectively selected from a database of prospectively collected data. The inclusion criteria were as follows: patients with osteochondritis dissecans; isolated single lesions, multiple lesions or bipolar lesions; and minimum 2 years of follow-up. Chondral surface damage was graded after debridement to allow for a better understanding of the lesion characteristics (when applicable) using the Outerbridge classification: grade 0 (normal), grade I (softening and swelling), grade II (partial-thickness defect with fissures that do not reach subchondral bone or exceed 1.5 cm in diameter), grade III (fissuring to the level of subchondral bone in an area with a diameter more than 1.5 cm), or grade IV

(exposed subchondral bone).[17] Patients were then grouped into 2 groups according to the presence or absence of an FTD (in the same compartment as the MAT), as determined via intraoperative Outerbridge grades: "no defect" (Outerbridge 0-I; ND) and "full-thickness defect" (Outerbridge IV; FTD). The exclusion criteria were those with missing PROs, with a moderate Outerbridge grade (II and III) —whether treated or neglected—given the poorer reliability of grading intermediate lesions,[18] and patients with grade IV defects at the time of MAT surgery that went untreated (so all patients with FTD in the included group had undergone a cartilage restoration surgery). Patients with FTD were noted for the type of the cartilage restoration procedure performed concurrently with MAT.

MAT was generally indicated for patients ideally younger than 50 years of age, who had persistent pain in the meniscectomized compartment. Patients with diffuse arthritic changes, inflammatory arthritis, marked obesity, or substantial joint-space narrowing are not appropriate for this surgical procedure. Patients with coronal malalignment and/or cruciate ligament insufficiency require concurrent or staged procedures (specifically high-tibial osteotomy for varus or distal femoral osteotomy for valgus knees, and anterior cruciate ligament reconstruction [ACLR], respectively). In the senior author's (B.J.C.) preferred technique, osteotomies are performed after the index MAT because of the significant abduction or adduction moments required during MAT that could otherwise damage the osteotomy.[19] The senior author's preferred techniques for concurrent MAT and ACLR have been previously published as well.[20] All lateral MAT patients used a bridge-in-slot surgical technique (as described in prior literature by the senior author),[8] as did most medial MAT patients (patients with surgical dates before 2005 received a keyhole technique [between 12 and 15 of the 56 medial MAT patients]).

Cartilage restoration treatment decisions were guided more by the depth/grade of the lesion rather than size. Defects of the femur >5 mm and ≥grade III were generally treated. Osteochondral allograft was used when subchondral bone was involved on the magnetic resonance imaging, typically the femoral condyle, or failed prior cartilage procedure. ACI was used as a primary surface procedure for lesions >2 cm^2 that have no subchondral bone involvement, and most commonly within the patellofemoral joint or very young patients (<18 years old). Microfracture was performed for smaller lesions of the femur <1 cm^2, and for most lesions of the tibia that were greater than or equal to grade III lesions. Osteochondral autograft was performed in lesions <10 mm diameter, typically when the femoral condyle was involved. Finally, DeNovo was incorporated for surface lesions, often of the femur.

Demographic data were recorded including the following: patient gender; date of surgery; body mass index; age at surgery: occurrence, number, timing and specific details of surgeries before the index MAT; and laterality of knee (right/left) and MAT (medial/lateral). The following intraoperative characteristics at the time of MAT were documented as well: presence of cartilage damage, grade of cartilage damage (after debridement to allow for a better understanding of the lesion characteristics), size and location (tibial plateau, femoral condyle, or patellofemoral) of cartilage defects, and concomitant procedures performed. Malalignment procedures (distal femoral or high tibial osteotomy) and ACLR procedures when applicable were performed at the time of index MAT.

Statistical Analysis

Postoperative data including complications, subsequent operations, and failures (revision MAT and conversion to TKA) were analyzed. PRO measures were obtained preoperatively and at 2-year and final follow-up postoperatively; these included Lysholm, International Knee Documentation Committee (IKDC), Knee Injury and Osteoarthritis Outcome Score (KOOS) with all five subsets, and Short Form (SF)-12 physical and mental. Western Ontario and McMaster Universities osteoarthritis index (WOMAC) scores for pain, stiffness, function, and total subsets were derived from the KOOS measures. Subjective questionnaire scores for "overall knee function" and "symptom rate" were documented as well to quantify patients' subjective feelings of knee function and overall symptoms. Where available, individual PRO changes (preoperative to 2-year and final follow-up) were compared with reported MCIDs to assess for clinically significant improvements from baseline for individual PROs independently for ND- and FTD-group patients.

Continuous variables are presented as mean ± standard deviation, and intergroup comparisons were made by means of independent sample *t*-tests. Categorical variables were presented as frequency counts and comparisons were made by means of χ-square. PRO delta scores were calculated by subtracting either the 2-year or final follow-up score from the preoperative score. All statistical comparisons were performed using SPSS software (IBM, Armonk, NY). Because of the large number of PRO comparisons made, we used a Bonferroni-adjusted P value of $< .003$ (15 comparisons were made in total). Statistical significance was set at $P < .05$ for all other testing.

Results

In total, 457 patients were identified to have undergone MAT during the study period; however, a total of 91 patients met the inclusion criteria, including 22 patients with ND (grade 0/I) chondral grading and 69 with FTD (grade

IV) grading who were treated by the cartilage restoration means (Fig 1). In the FTD group, the most of defects (50.7%) were on the medial femoral condyle, with the second most common location being the lateral femoral condyle (39.1%), correlating with the location of MAT. The mean overall chondral lesion size was $4.43 \pm 2.5\ cm^2$. There were no significant demographic differences between groups in regard to patient age, body mass index, or mean number of prior surgeries before the index MAT procedure (Table 1). Tables 1 and 2 detail information for each patient group on prior surgical intervention, concomitant procedures, cartilage restoration procedures, and complications. The ND group and FTD group were followed for a mean 4.48 ± 2.63 and 3.84 ± 2.47 years, respectively. Only 1 complication occurred in the FTD patient series (1.3%; ACLR femoral fixation screw fracture), with none in the ND patient series after MAT performance. There were no significant differences between the ND and FTD groups in terms of the number of subsequent surgeries or failure by revision MAT or conversion to TKA. The mean time to revision MAT in the ND group was 2.31 years (n = 2; 10.0%), and 2.69 years (n = 10; 15.2%; $P = .801$) in the FTD group after MAT. The mean time of conversion to TKA in the ND group was 6.44 years (n = 1; 5.0%), and 6.19 years (n = 2; 3.1%; P = N/A) in the FTD group after MAT.

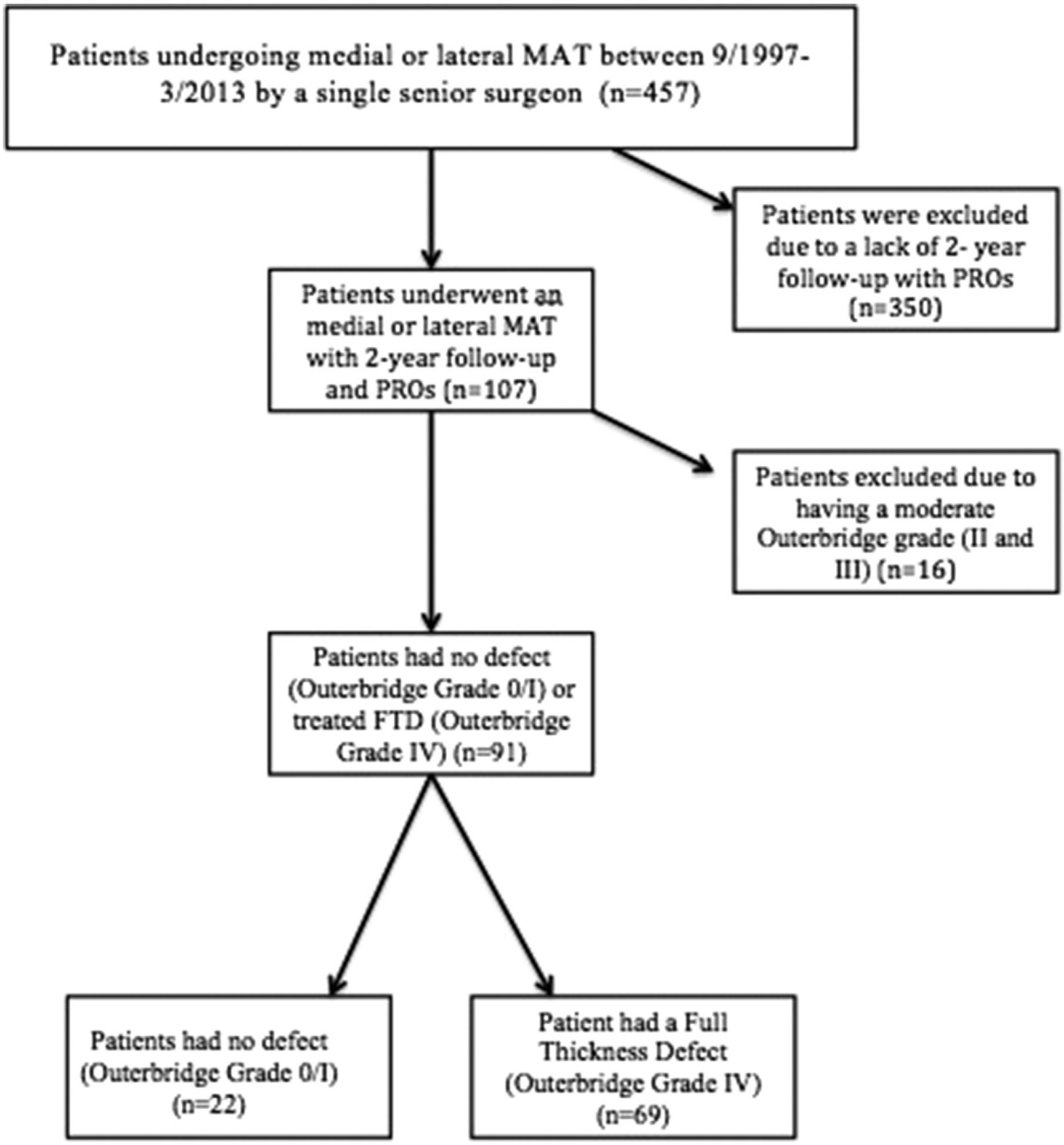

Fig 1. Flowchart demonstrating patient exclusions to end up with the final patient cohort for analysis. (FTD, full-thickness defect; MAT, meniscus allograft transplantation; PROs, patient-reported outcomes.)

Table 1. Comparison of Patient Demographics

Demographic Variable	"No Defect" (Grade 0/I Defects)	"Full-Thickness Defect" (Grade IV Defects)	*P* Value
No. of overall patients	22	69	—
BMI	25.3 ± 4.3	25.8 ± 7.6	.671
Age at surgery, yr	26.8 ± 10.7	30.4 ± 10.3	.159
Male gender, n (%)	14 (63.6%)	32 (46.4%)	.075
Final follow-up, n (%)	4.48 ± 2.63	3.84 ± 2.47	.305
Right knee, n (%)	14 (53.8%)	45 (65.2%)	.709
Medial MAT, n (%)	17 (77.3%)	39 (56.5%)	**.030**
Patients with prior…, n (%)			
Surgery (any)	22 (100%)	67 (97.1%)	.090
Chondroplasty	7 (31.8%)	33 (47.8%)	.330
Meniscectomy	19 (86.4%)	57 (82.6%)	.261
ACL reconstruction	9 (40.9%)	18 (26.1%)	.111
Cartilage procedure	2 (9.1%)	13 (18.8%)	.358
MAT	0 (0%)	0 (0%)	—
Mean no of prior surgeries	1.9 ± 0.9	2.3 ± 0.9	.118

NOTE. Boldface indicates statistical significance ($P < .05$). "Cartilage procedure" refers to such interventions as microfracture, autologous chondrocyte implantation, DeNovo particulate cartilage grafting, osteochondral auto/allograft.

ACL, anterior cruciate ligament; BMI, body mass index; MAT, meniscal allograft transplantation.

There were no significant differences between PROs preoperatively between groups (Table 3). When comparing delta PROs between the ND and FTD groups, no significant differences were observed at either the 2-year or final follow-up time points (Table 4). Positive deltas indicate an improvement in the underlying PRO score with the exception of WOMAC. A negative WOMAC delta PRO indicates an improvement in patient functional outcomes. All PRO deltas showed an improvement from baseline with the exception for SF-12 mental in the ND group (Figs 2-4).

Table 5 reports the MCID provided within the orthopaedic literature for each of the reported PRO scoring scales. Only Lysholm, IKDC, KOOS (pain, symptoms, ADL, sport, QOL), and WOMAC have reported MCIDs or minimal important change data for

Table 2. Comparison of Intraoperative/Postoperative Finding Demographics

Variable	"No Defect" (Grade 0/I Defects)	"Full-Thickness Defect" (Grade IV Defects)	*P* Value
No. of overall patients	22	69	—
Complications, n (%)	0 (0%)	1 (1.4%)	.589
Defect location, n (%)	—		—
MFC	—	35 (50.7%)	
LFC	—	27 (39.1%)	
Trochlea	—	5 (7.2%)	
MTP	—	2 (2.9%)	
LTP	—	5 (7.2%)	
Concomitant procedures, n (%)	—	—	—
ACLR	8 (38.1%)	8 (11.8%)	**.004**
Cartilage procedure	0 (0%)	69 (100.0%)	**<.001**
OA	—	48 (69.6%)	
ACI	—	13 (18.8%)	
MFx	—	9 (13.0%)	
OATS	—	3 (4.3%)	
DeNovo	—	1 (1.4%)	
Realignment procedure	2 (9.1%)	7 (10.1%)	.986
Mean no. of subsequent surgeries	0.5 ± 0.8	0.4 ± 0.7	.378
Revision MAT	2 (10.0%)	8 (12.9%)	.845
Conversion to TKA	1 (5.0%)	2 (3.3%)	.646

NOTE. Boldface indicates statistical significance ($P < .05$). For some categories, the "n" adds up to greater than the number of overall patients in the series. For instance, some patients had more than one concomitant surgery, or more than one defect location, and thus their "n" was counted independently for each subcategory. "Realignment procedure" refers to either opening or closing wedge high tibial osteotomy or distal femoral osteotomy procedures.

ACI, autologous chondrocyte implantation; ACLR, anterior cruciate ligament reconstruction; LFC, lateral femoral condyle; LTP, lateral tibial plateau; OA, osteochondral allograft; OATS, osteochondral autograft transfer system; MAT, meniscal allograft transplantation; MFC, medial femoral condyle; MFx, microfracture; MTP, medial tibial plateau; TKA, total knee arthroplasty.

Table 3. Comparison of Preoperative Patient-Reported Outcomes

PRO	"No Defect" (Grade 0/I Defects)	"Full-Thickness Defect" (Grade IV Defects)	*P* Value
Lysholm	41.5 ± 22.3	43.4 ± 17.4	.753
IKDC	34.3 ± 19.9	36.2 ± 15.3	.707
KOOS			
Pain	54.0 ± 16.3	55.0 ± 15.5	.851
Symptoms	56.4 ± 25.6	52.4 ± 18.1	.488
ADL	60.7 ± 25.4	68.3 ± 18.4	.229
Sport	24.3 ± 21.3	24.1 ± 20.0	.981
QOL	24 ± 15.5	27.1 ± 17.6	.563
WOMAC			
Pain	7.2 ± 3.7	7.1 ± 3.6	.917
Stiffness	3.4 ± 2	3.6 ± 1.8	.776
Function	26.7 ± 17.2	21.6 ± 12.5	.229
Total	33.8 ± 18	32.3 ± 16.6	.792
Overall knee function	3.2 ± 2.3	3.1 ± 1.6	.888
Symptom rate	4.7 ± 2.5	5.1 ± 2.2	.611
SF-12 physical	34.5 ± 5.6	38.4 ± 7.6	.092
SF-12 mental	50.6 ± 15.8	52.6 ± 10.0	.676

ADL, activities of daily living; IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; PRO, patient-reported outcome; QOL, quality of life; SF-12, Short Form-12; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

Table 4. PRO Deltas Comparing Preoperative to 2-Year and Final Follow-up

	PRO	"No Defect" (Grade 0/I Defects)	"Full-Thickness Defect" (Grade IV Defects)	*P* Value
Two-year follow-up delta PROs	Lysholm	19.2 ± 12.7†	22.9 ± 15.6†	.665
	IKDC	19.2 ± 14.0†	22.2 ± 17.4†	.763
	KOOS			
	Pain	19.9 ± 14.0†	16.3 ± 13.9	.668
	Symptoms	13.8 ± 11.7†	15.3 ± 15.4†	.853
	ADL	14.0 ± 9.8	16.1 ± 14.4	.801
	Sport	13.8 ± 13.0†	25.6 ± 22.3†	.469
	QOL	36.5 ± 22.5†	18.2 ± 22.0†	.170
	WOMAC*			
	Pain	−2.7 ± 2.2	−2.5 ± 2.3	.906
	Stiffness	−1.6 ± 1.2	−1.1 ± 1.9	.646
	Function	−9.5 ± 6.6†	−11.0 ± 9.8†	.801
	Total	−13.7 ± 9.7†	−13.9 ± 12.0†	.973
	Overall knee function	3.3 ± 2.5	3.0 ± 2.6	.836
	Symptom rate	2.7 ± 1.0	1.4 ± 1.4	.410
	SF-12 physical	4.5 ± 4.3	3.1 ± 5.3	.711
	SF-12 mental	4.9 ± 5.4	−0.5 ± 6.3	.243
Final follow-up delta PROs	Lysholm	14.8 ± 14.4†	21.1 ± 19.8†	.410
	IKDC	15.3 ± 14†	24.2 ± 23.1†	.301
	KOOS			
	Pain	13.6 ± 13.4	17.6 ± 17.1†	.549
	Symptoms	11.3 ± 12†	15.2 ± 19.3†	.530
	ADL	10.1 ± 9.4	17.3 ± 17.4	.279
	Sport	8.3 ± 12	28.0 ± 28.2†	.153
	QOL	20.5 ± 22.6†	23.1 ± 26.6†	.783
	WOMAC*			
	Pain	−1.7 ± 2.1	−2.7 ± 3.2	.389
	Stiffness	−0.9 ± 1.4	−1.1 ± 2.3	.806
	Function	−6.9 ± 6.4†	−11.8 ± 11.8†	.278
	Total	−9.9 ± 9.2	−14.8 ± 15.4†	.420
	Overall knee function	2.3 ± 2.7	3.1 ± 3.0	.402
	Symptom rate	2.9 ± 0.9	1.1 ± 1.9	.173
	SF-12 physical	5.2 ± 8.3	2.5 ± 6.9	.395
	SF-12 mental	−0.8 ± 9.7	0.5 ± 8.7	.741

ADL, activities of daily living; IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; PRO, patient-reported outcome; QOL, quality of life; SF-12, Short Form-12; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

*Negative WOMAC deltas indicate an improvement in PRO.

†Improvement from preop. exceeds minimal clinically important difference.

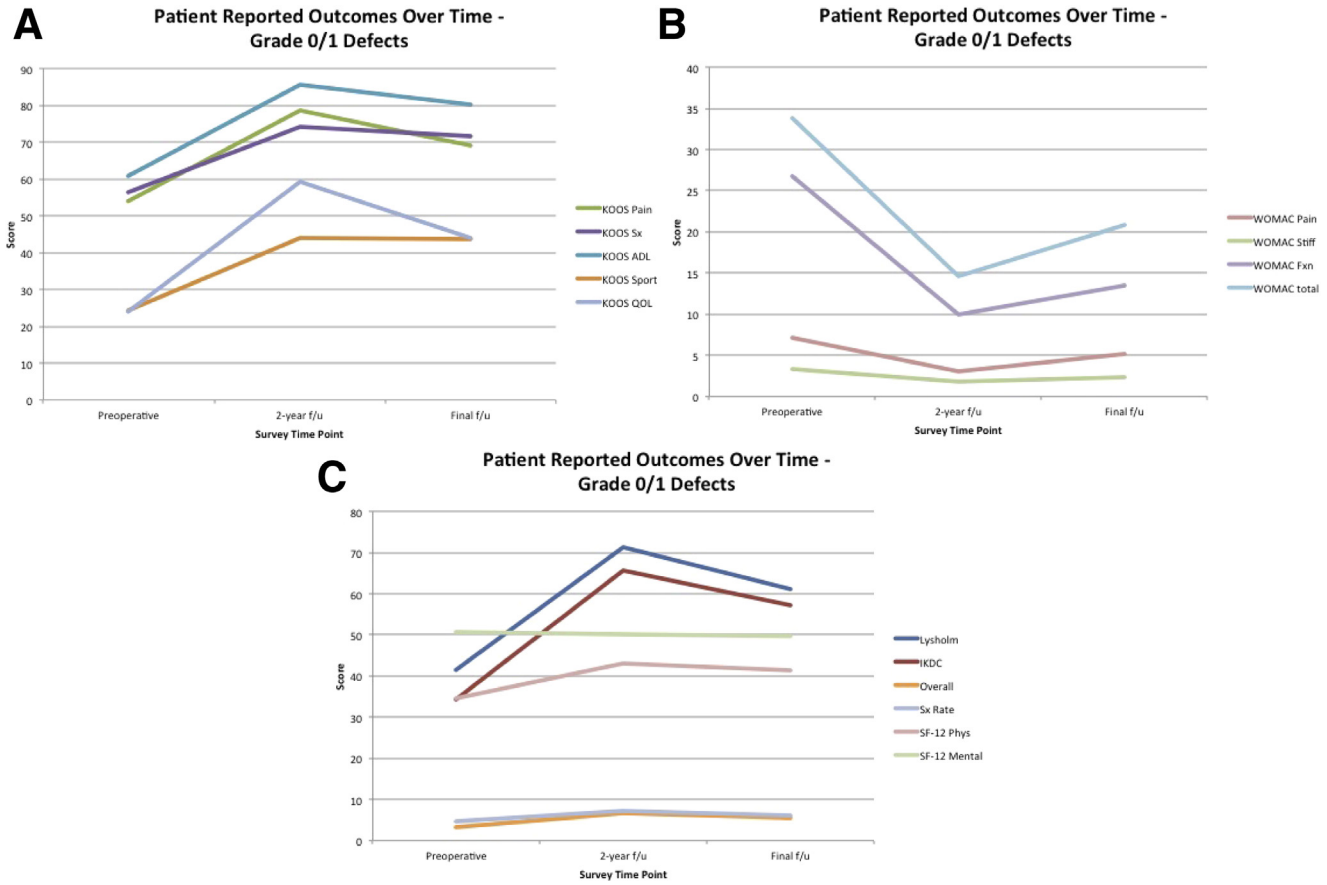

Fig 2. Patient-reported outcomes over time for MAT with grade 0/I defects ("no defect" group). (A) KOOS; (B) WOMAC; and (C) Lysholm, IKDC, Overall, Sx Rate, and SF-12 patient-reported outcome scores are shown. (ADL, activities of daily living; Fxn, function; IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcomes Score; QOL, quality of life; Sx, symptom; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.)

which to compare. SF-12 (physical and mental), overall knee function, and symptom rate do not have reported MCIDs related to this patient population for which to compare. In the ND group, delta PROs at 2 years postoperatively met MCID for Lysholm, IKDC, KOOS pain, KOOS symptoms, KOOS sport, KOOS QOL, WOMAC function, and WOMAC total; and delta PROs at the final follow-up met MCID for Lysholm, IKDC, KOOS symptoms, KOOS QOL, and WOMAC function. In the FTD group, delta PROs at 2 years postoperatively met MCID for Lysholm, IKDC, KOOS symptoms, KOOS sport, KOOS QOL, WOMAC function, and WOMAC total; and delta PROs at the final follow-up met MCID for Lysholm, IKDC, KOOS pain, KOOS symptoms, KOOS sport, KOOS QOL, WOMAC function, and WOMAC total.

Discussion

At 2-year and final follow-up postoperatively, there were no differences observed in delta PRO scores when comparing between groups. There were additionally no differences in complications or failure between those with ND or FTD diagnosed intraoperatively. The results of the current study suggest that chondral damage identified and treated by the cartilage restoration means at the time of MAT may not affect the clinical outcomes of MAT.

Prior studies have shown that MAT is a viable surgical option for patients with severe cartilage damage in the setting of meniscal deficiency, although they have not provided a direct comparison to a series of MAT patients with low-grade chondral damage and have not compared those with articular cartilage repair with those without. Stone et al.[16] evaluated 49 patients with moderate to severe cartilage damage (41 with grade IV and 8 with grade III changes) who underwent MAT. The authors reported that 73.5% were able to participate in sporting activities postoperatively, but 11 (22.4%) patients failed at an average of 5.2 years with a Kaplan-Meier survival estimate of 12.6 years. Harris et al.[21] reported on 14 patients who underwent cartilage repair with concomitant lateral MAT and found significant improvements in multiple PROs. They compared this concurrent treatment group with those who underwent isolated articular cartilage surgery and found lower KOOS QOL scores. Abrams et al.[22] found significant improvements in Lysholm, IKDC, and all

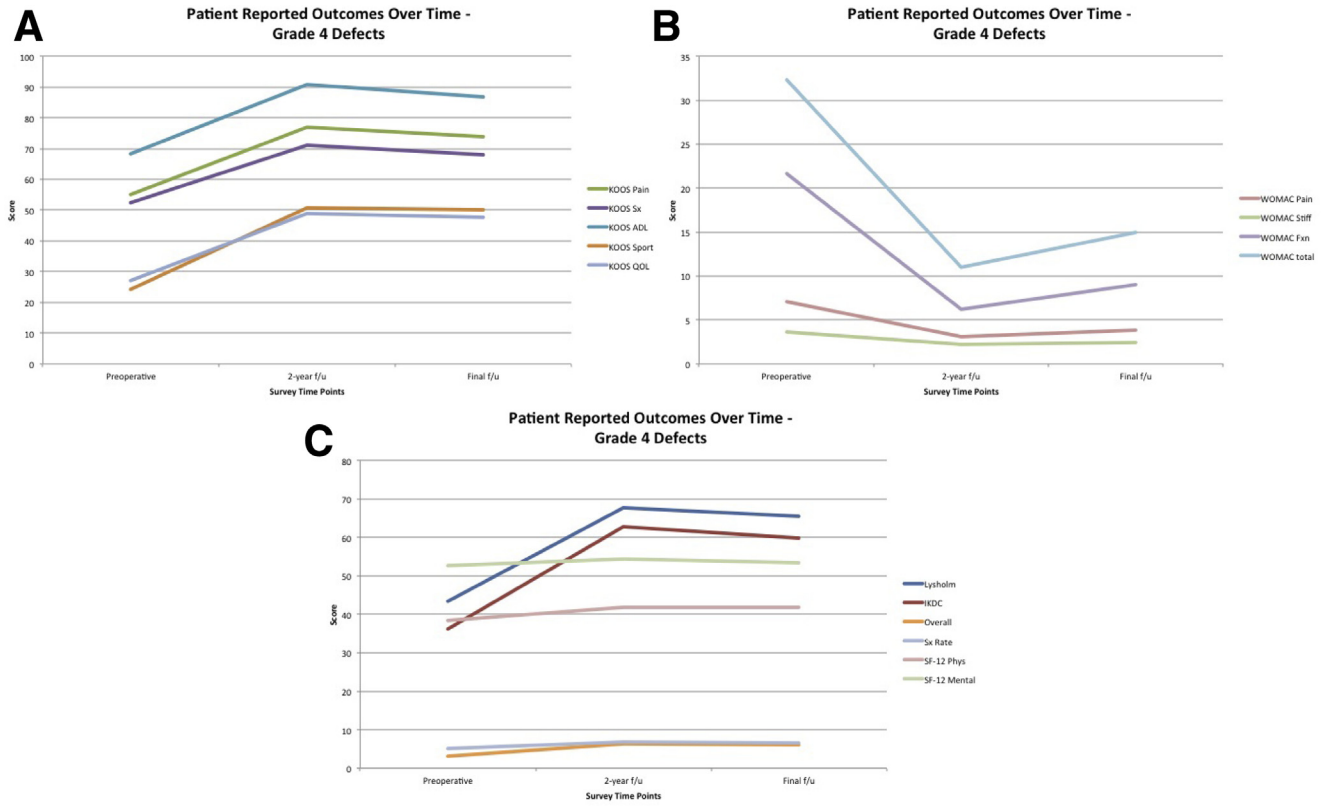

Fig 3. Patient-reported outcomes over time for MAT with grade IV defects ("full-thickness defect" group). (A) KOOS; (B) WOMAC; and (C) Lysholm, IKDC, Overall, Sx Rate, and SF-12 patient-reported outcome scores are shown. (ADL, activities of daily living; f/u, follow-up; Fxn, function; IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcomes Score; QOL, quality of life; SF, Short Form; Sx, symptom; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.)

KOOS subdomain scores for 32 patients at 4.2 years postoperatively from combined MAT and femoral osteochondral allograft transplantation, with significantly greater increases when condylar defect sizes were less than 4 cm^2. Rue et al.[23] reported on 30 patients with combined MAT and cartilage restoration procedures, and reported significant improvements in most PROs and patient satisfaction metrics.

This study compares a group of patients with no cartilage defect with those with treated full-thickness defects who underwent MAT. Overall, we found low failure rates and improvement in PROs after MAT in either group—exceeding MCID in similar PROs at both 2-year and final follow-up—irrespective of the presence or absence of FTD treated at the time of MAT. Our findings are similar to those reported in the literature after MAT,[5,6,10-15,24] and we believe that our study findings challenge the traditional clinical indications for MAT in terms of cartilage status at the time of surgery. Our results suggest that patients with full-thickness grade IV chondral injury can achieve the same success as their counterparts with no cartilage defect (grade 0/I) in the affected compartment so long as the defect is addressed. It should be noted that many of these cartilage restoration procedures require at least a 2-year maturation process, so those responding particularly favorably in the first 6 months of surgery may be experiencing a placebo-type effect or any other number of confounding variables that we cannot presently identify. Overall, clinicians performing MAT in meniscus-deficient patients with FTD should counsel their patients that they can expect similar outcomes to patients without FTD at long-term follow-up as long as the defect is treated.

Limitations

Our study is not without limitations. Our overall patient series size is relatively small (n = 91 patients), particularly for patients with ND (n = 22). However, in comparison to the available literature on MAT, these patient numbers are relatively sizeable and appropriate to garner outcomes and comparison data from. Because the meniscal transplant procedure—and performance of concurrent cartilage or ligamentous procedures—is technically challenging, it is likely that that experience, case volume, and a steep learning curve play a role in outcomes, and thus the results from our single surgeon patient series may not be entirely generalizable

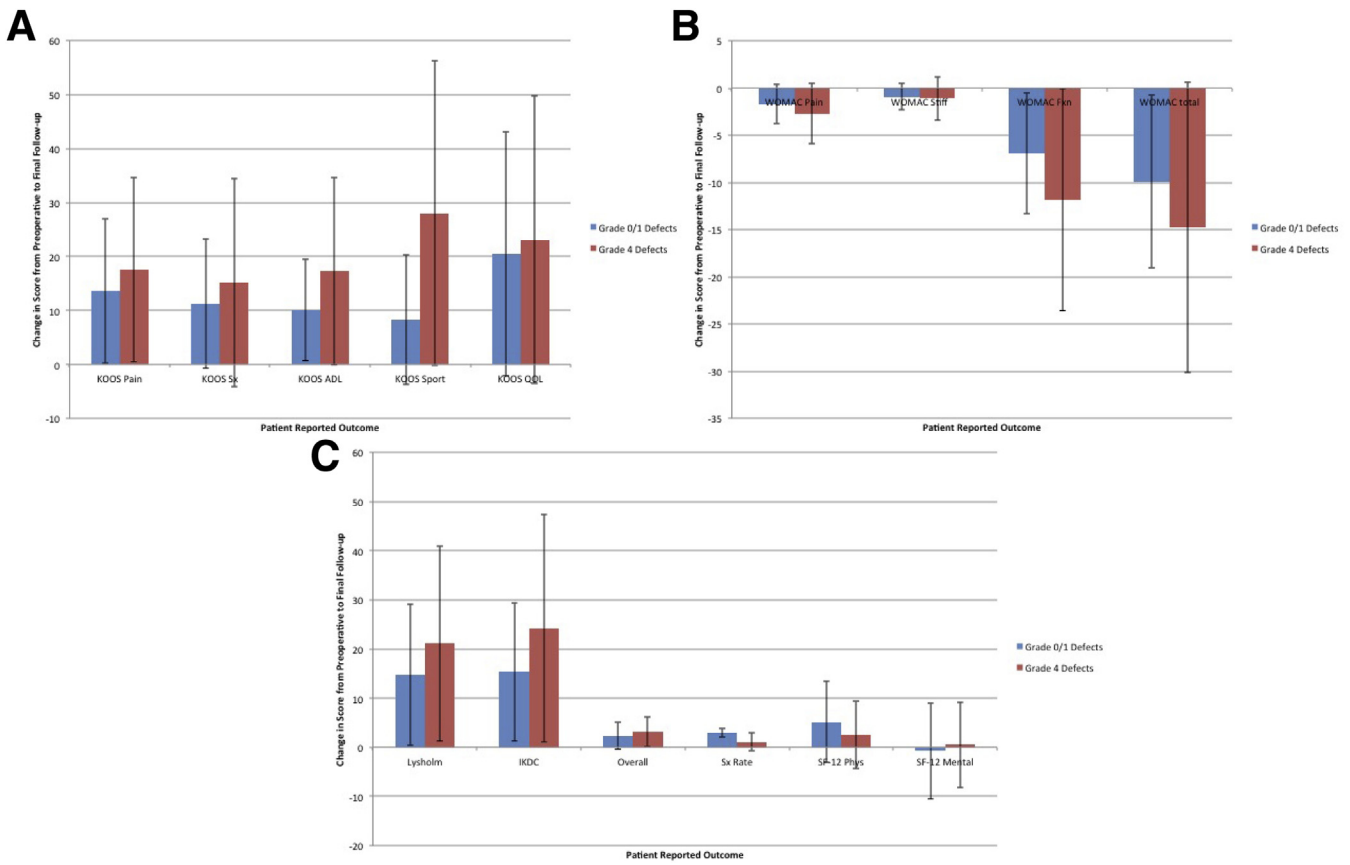

Fig 4. Change from preoperative to final follow-up in patient-reported outcomes. (A) KOOS; (B) WOMAC; and (C) Lysholm, IKDC, Overall, Sx Rate, and SF-12 patient-reported outcome scores are shown. (ADL, activities of daily living; Fxn, function; IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcomes Score; QOL, quality of life; SF, Short Form; Sx, symptom; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.)

to surgeons with smaller case volumes of this genre. Some patients underwent additional concomitant procedures (realignment procedures, ligamentous reconstructions) at the time of MAT surgery, which may confound resultant data. Specifically, there were a significantly higher percentage of patients who underwent ACLR in the ND group; this may represent a different patient population, and certainly has implications regarding patient rehabilitation and recovery. There was heterogeneity as well in terms of defect location, which could confound results. In addition, we acknowledged that the FTD group was heterogeneous, with defects treated by various methods, and this explained the performance of our post hoc subgroup analysis. This subgroup analysis did not allow for an appropriate statistical comparison in the subgroup of those patients who received cartilage treatment (i.e., microfracture vs osteochondral allo/autografting vs DeNovo vs autologous chondrocyte implantation) by the type of treatment received, or the location of the chondral defect. However, our comparison showed no difference in failures or complications at the final follow-up based on whether an FTD (grade IV) was treated with a cartilage restoration procedure at the time of MAT. There were no differences seen in the comparison between subgroups for any PRO at any postoperative time period, or when comparing the change in individual PROs from preoperative to the final follow-up. Thus, our method in grouping these patients together was valid for the overall analysis, and it suggests that future studies should look further at the influence of concomitant cartilage restoration procedures on outcomes after MAT. With regard to MCID, we were limited in that not all of our PROs have documented MCIDs in the literature with which to compare; although, given that our hypothesis was a comparison of delta PROs between ND- and FTD-group patients rather than an intragroup evaluation of patient improvement levels, this is not detrimental to the overall purpose of our study.

Moreover, our intent was to make the patient groups in a somewhat binary fashion (being either ND or FTD) in terms of chondral damage, but our data thus do not provide comparisons for those patients with grade II or grade III damage, which is a demographic of patients that will require future study efforts. It should finally be

Table 5. Minimal Clinically Important Differences for Patient-Reported Outcome Scoring Scales

PRO	MCID/MIC
Lysholm	10.1 (MCID)
IKDC	3.19 (MCID)
KOOS	—
Pain	16.7 (MIC)
Symptoms	10.7 (MIC)
ADL	18.4 (MIC)
Sport	12.5 (MIC)
QOL	15.6 (MIC)
WOMAC	—
Pain	7.5 (MCID)
Stiffness	6.3 (MCID)
Function	5.89 (MCID)
Total	11.5 (MCID)
Overall knee function	N/A
Symptom rate	N/A
SF-12	—
Physical	N/A
Mental	N/A

ADL, activities of daily living; IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; MCID, minimal clinically important difference; MIC, minimal important change; N/A, not available; PRO, patient reported outcome; QOL, quality of life; SF-12, Short Form-12; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

noted that an ideal "control" group for comparison to show the impact of the surgical treatment of the FTD is a group of patients with FTD who undergo cartilage surgery with MAT versus a group of patients with FTD who undergo just MAT and leave the isolated FTD alone; however, such a "control" group is not present in our senior surgeon's practice. Finally, in a study of this genre, there is always the possibility of beta error in terms of statistical comparisons and analyses.

Conclusions

When comparing a patient series with FTD who underwent MAT with a patient series with ND, there were no differences in the change in individual PROs from preoperative to the final follow-up. Similarly, there were no differences in complications or failure between those with ND or FTD diagnosed intraoperatively. The results of the current study suggest that chondral damage identified and treated by the cartilage restoration means at the time of MAT may not affect the clinical outcomes of MAT.

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