Clinical Outcomes of Multifocal Osteochondral Allograft Transplantation of the Knee

An Analysis of Overlapping Grafts and Multifocal Lesions

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Background: There is a paucity of literature regarding the outcomes of adjacent-plug osteochondral allograft transplantation (OCA) for irregular or ovoid lesions and multifocal OCA for multicompartmental, focal lesions.

Purpose: To quantify the survival of multiplug OCA for larger, high-grade chondral lesions with the ''snowman'' technique versus that of multicompartmental or bipolar OCA.

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

Methods: All patients who underwent primary, multiplug OCA for large unicondylar, multicompartmental (eg, bipolar patellofemoral and condylar, bicondylar), or bipolar chondral defects (ie, patellofemoral) with a minimum 2-year follow-up by a single surgeon from April 1, 2003, to April 1, 2015, were analyzed. Failure was defined as revision OCA, conversion to arthroplasty, or gross appearance of graft degeneration on second-look arthroscopic surgery.

Results: Twenty-six patients (28 knees) were identified, with 22 patients (24 knees; 50% female; mean age, 31.9 $\pm$ 9.1 years) having at least 2-year clinical follow-up (85.7%). Nine patients (9 knees) underwent isolated, condylar OCA with the snowman technique and had a mean follow-up of 7.4 $\pm$ 3.6 years (range, 1.38-11.14 years), while 13 additional patients (15 knees) underwent multifocal OCA and had a mean follow-up of 6.4 $\pm$ 3.9 years (range, 2.07-12.38 years). Reoperations were common, with 44.4% (n = 4) of the snowman group and 20.0% (n = 3) of the multifocal group undergoing at least 1 reoperation. There were 3 failures (33.3%) in the snowman group at a mean 7.7 $\pm$ 5.5 years and 1 failure (6.7%) in the multifocal group at 4.5 $\pm$ 0.0 years, with all undergoing secondary total knee arthroplasty. Patients who underwent snowman OCA demonstrated significant postoperative improvement in the Knee injury and Osteoarthritis Outcome Score (KOOS) pain subscore and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) overall score ($P < .05$ for both). Patients who underwent multifocal OCA demonstrated significant improvement in the International Knee Documentation Committee score; KOOS symptoms, activities of daily living, sport, and quality of life subscores; WOMAC stiffness, function, and overall subscores; and 12-Item Short Form Health Survey physical component summary score ($P < .05$ for all).

Conclusion: Patients who underwent unicondylar, multiplug OCA using the snowman technique demonstrated inferior clinical outcomes, higher reoperation rates, and greater failure rates than those who underwent isolated single-graft transplantation. By contrast, multifocal OCA may be a viable knee preservation technique for young, active patients with multicompartmental chondral disease, leading to improved clinical outcomes and low reoperation and failure rates at midterm follow-up.

Keywords: osteochondral allograft transplantation; knee; cartilage; patellofemoral

Articular cartilage lesions of the knee joint are found in over 60% of knee arthroscopic procedures.[1,6] These lesions are often a source of significant pain and discomfort for patients and may progress to diffuse osteoarthritis throughout the knee.[7] Patients with large chondral or osteochondral lesions (>4 cm^2) present a unique clinical challenge as there are limited joint preservation options available for this specific patient population. In addition, partial knee arthroplasty and total knee arthroplasty (TKA) are generally undesirable treatment options in

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younger patients.[5,22,30] Cartilage repair and restoration procedures including marrow stimulation techniques, mosaicplasty, and autologous chondrocyte implantation have been shown to have decreasing efficacy in direct correlation with increasing lesion size or in patients who have failed previous surgery.[9,11,17,25,26] These concerns are magnified for young, physically active patients, especially for those undergoing marrow stimulation procedures.[11,23,27] Osteochondral allograft transplantation (OCA) has been demonstrated to be a viable single-stage cartilage restoration procedure that restores hyaline cartilage at the articular surface and addresses any underlying subchondral bone injury in patients with focal osteochondral lesions of the knee.[8,14,28]

To date, OCA has been consistently shown to be an effective primary[3] and salvage procedure for focal osteochondral defects of the knee, including for patients with lesions >2 cm^2 and typically in patients under the age of 50 years.[2,10,16,19,24,32] The vast majority of the existing literature has focused on single-plug OCA via the circular dowel technique or larger surface grafts via the shell technique for femoral condylar, trochlear, or patellar lesions. There is a paucity of research into the clinical outcomes of multifocal OCA, that is, OCA performed simultaneously in multiple compartments of an ipsilateral knee for patients with more widespread disease but with discrete, focal lesions. Bipolar osteochondral defects, defined as reciprocal lesions of both the tibia and femur or patella and trochlea, are also a distinct challenge. Previous reports on bipolar reciprocal OCA have demonstrated significant clinical improvement, but there are conflicting reports on the reoperation and failure rates, with some studies suggesting that reoperation and failure rates are higher than in published cohorts with unipolar, isolated lesions.[20,26] Patients who have multifocal or bipolar reciprocal lesions often have additional injuries of the knee, such as meniscal tears or insufficiency, but are less than 50 years of age and lead active lifestyles.[10] Furthermore, there are limited published data regarding the clinical outcomes of patients treated with OCA with the dowel technique, that is, 2 overlapping allograft plugs for a single, elongated, or oblique lesion in the knee.[18]

The purpose of this study was to (1) report the clinical outcomes of patients treated with multifocal OCA; (2) report the clinical outcomes of patients treated with overlapping grafts for irregular or ovoid lesions, the “snowman” technique; (3) compare the clinical outcomes of these groups with previously published literature including from our own institution; and (4) evaluate demographic, preoperative, and operative variables that may be associated with inferior outcomes. The authors hypothesized that both groups, multifocal OCA and snowman OCA, would have inferior clinical outcomes compared with the published literature on single-graft OCA for isolated unipolar lesions.

METHODS

After institutional review board approval (No. 15050301), consecutive patients who underwent either primary, fresh OCA with the snowman technique or multifocal OCA (ie, bipolar patellofemoral, patellofemoral and femoral condylar, or bicondylar femoral grafts) for the restoration of International Cartilage Repair Society grade IV articular cartilage defects with a minimum 2-year follow-up, or having failed OCA before 2-year follow-up, were retrospectively isolated from a prospectively collected single-surgeon (B.J.C.) database from April 1, 2003, to April 1, 2015. Indications for OCA included focal, symptomatic articular cartilage defects in ≥1 compartments of the knee. Specifically, for multicompartmental OCA, indications were narrow and included only patients with multiple, discrete articular cartilage lesions surrounded by otherwise healthy cartilage and preservation of the joint space. Patients were not excluded for having undergone previous ipsilateral knee surgery. Exclusion criteria were applied to any patients with the following: medication-induced avascular necrosis; isolated single-graft OCA of the knee; OCA at a site other than the patella, tibia, or distal femur; and revision OCA. Patients were not excluded for undergoing concomitant procedures at the time of OCA including corrective realignment osteotomy, meniscal allograft transplantation, meniscectomy, and/or ligamentous reconstruction.

Demographic information, medical and/or surgical history, intraoperative findings, and postoperative data were collected. A complete list of variables can be found in Table 1. The Kellgren-Lawrence grade was determined for each knee based on preoperative radiographs. For all patients, validated preoperative and minimum 2-year postoperative

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TABLE 1
Demographic, Surgical History, Operative, and Postoperative Variables Collected for Analysis

Demographic/preoperative variables	Age at date of surgery
	Sex
	Body mass index
	Symptom duration
	Smoking status
	Workers' compensation
	Preoperative Kellgren-Lawrence grade on radiographs
Surgical history variables	Number of previous surgeries
	Failed previous cartilage surgery
	Type of failed previous cartilage surgery
Operative variables	Laterality
	Number of grafts
	Location of grafts
	Aggregate size of lesion(s)
	Concomitant procedures including meniscal allograft transplantation, ligament repair or reconstruction, cartilage procedure, and/or osteotomy
Postoperative variables	Complications
	Reoperations
	Validated patient-reported outcome scores at a minimum 2 years after surgery

patient-reported outcomes including the Lysholm score, International Knee Documentation Committee (IKDC) score, Knee injury and Osteoarthritis Outcome Score (KOOS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score, and 12-Item Short Form Health Survey (SF-12) physical and mental component summary scores were prospectively collected. Patients were divided into 2 separate groups for the purposes of data analysis and not directly compared with each other as the authors believe their lesions to be different in nature. One group (snowman group) consisted of patients who underwent OCA for a single osteochondral lesion of the femoral condyle with the snowman technique, and the second group (multifocal group) consisted of patients who underwent OCA in >1 compartment within the ipsilateral knee.

Reoperations and complications were analyzed for both groups, with the reoperation rates, time to reoperation, procedures performed, and findings at the time of reoperation noted. Major complications were considered deep infections, complex regional pain syndrome, and stiffness requiring surgical lysis of adhesions. A reoperation was defined as any procedure performed after the index surgery in which a patient was taken to the operating room, including second-look arthroscopic surgery, surgical debridement, chondroplasty, hardware removal, revision OCA, or conversion to knee arthroplasty. Indications for second-look arthroscopic surgery included stiffness, mechanical symptoms, and pain either from a traumatic event on the surgical knee or persistent pain postoperatively. Failure was defined as revision OCA, conversion to arthroplasty, or gross appearance of graft degeneration on second-look arthroscopic surgery.

Surgical Technique for Fresh OCA

The senior author's (B.J.C.) surgical technique for OCA of the distal femur and/or patella has been previously described.[10,14] Under general anesthesia, patients were positioned supine on the operating table. After an examination under anesthesia, diagnostic arthroscopic surgery was performed to visually confirm the osteochondral defects and identify any other existing abnormalities. Concomitant procedures such as meniscectomy, meniscal allograft transplantation, osteotomy, or ligament reconstruction were performed first to prevent any iatrogenic injury to the newly restored articular cartilage. If the snowman technique was performed for a femoral condylar lesion, parapatellar mini-arthrotomy was performed on the ipsilateral side of the patellar tendon as the defect. The patella was retracted with a Z retractor, allowing for the identification of the defect site and determination of the defect size (Figure 1). The osteochondral allograft was then placed in room-temperature sterile saline on the back table. A cannulated, cylindrical sizing guide was placed flush on the defect to determine the optimal graft diameter, and a guide pin was drilled through the sizing guide into the appropriate location. The sizing guide was removed, and a cannulated bone reamer was placed over the guide pin to ream to a depth of 6 to 8 mm (Figure 2). A ruler was used to measure the depth of each reamed defect at the 12-, 3-, 6-, and 9-o'clock positions. On the back table, the donor allograft was prepared, and a bushing was firmly held by an assistant over the desired harvest location. A donor harvester was used to create an allograft cylinder that matched the reamed diameter. An assistant used forceps to secure the cylinder without damaging the articular cartilage, and a sagittal saw was used to cut each allograft to the measured depth, which typically included less than 6 mm of subchondral bone. Pulsatile lavage with bacitracin-mixed saline was used to copiously irrigate both the implantation site and the allograft plug. Each allograft plug was then press-fit by hand, an oversized tamp was used to gently assist impaction, and the 2 plugs were touching each other (Figure 3).

The steps for multicompartmental OCA were the same as described above for the snowman technique, with the exception that multiple compartments were grafted and only a single dowel plug was grafted per osteochondral

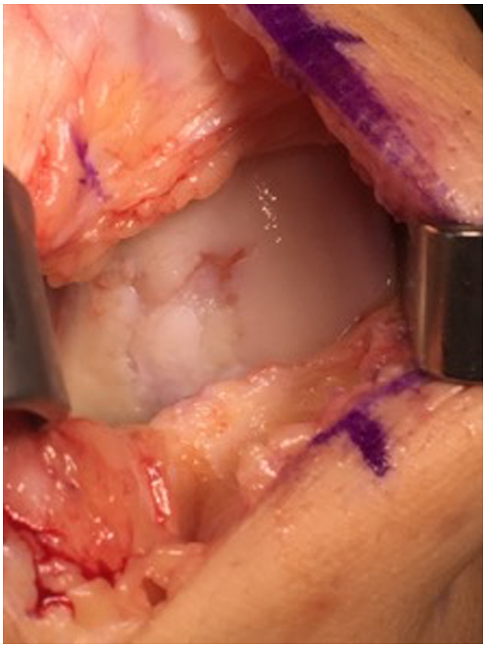

Figure 1. Intraoperative image of the right knee in a 26-year-old male patient lying supine and the knee in flexion. A medial femoral condylar osteochondral lesion is identified through a medial arthrotomy incision.

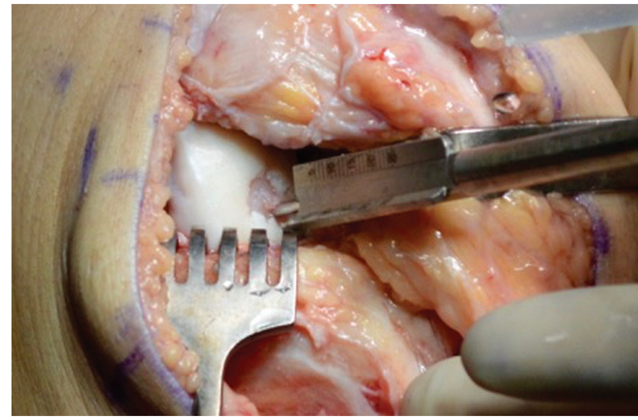

Figure 2. Intraoperative image from the same 26-year-old male patient demonstrating a 20 mm–diameter lateral femoral condylar defect. A cannulated cutting reamer is being used to drill to a depth of approximately 6 to 8 mm.

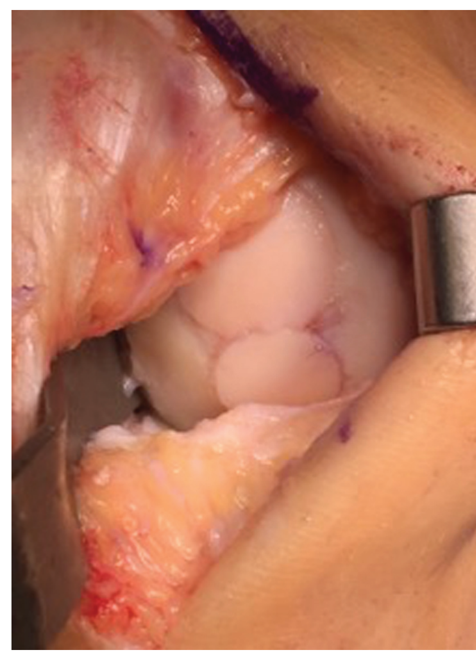

Figure 3. Intraoperative image from the same 26-year-old male patient demonstrating treatment of the medial femoral condylar lesion using the snowman technique with a 20 mm–diameter osteochondral allograft press-fit superiorly and a 15 mm–diameter osteochondral allograft press-fit inferiorly.

lesion. When a defect was present in the patellofemoral compartment, OCA was first performed there before addressing the tibiofemoral lesions. To access the articular surface of the patella or the femoral trochlea, a 10-cm midline incision was made from the superior aspect of the patella to the tibial tubercle. After graft implantation and copious irrigation, layered closure was performed at the site of the surgical incision.

Rehabilitation Protocol

All patients were instructed to follow heel-touch weightbearing for the first 6 weeks postoperatively. Additionally, patients wore a hinged knee brace locked in full extension that was only removed for exercises. After 2 weeks, the brace was discontinued to allow a progressive increase in range of motion (ROM), and exercises were advanced as tolerated to include patellar and tibiofibular joint mobilization as well as quadriceps, hamstring, and gluteus strengthening. Weightbearing was advanced as tolerated beginning 6 weeks postoperatively, and patients were to achieve full weightbearing by 8 weeks. At that time, exercises were advanced to include gait training and closed kinetic chain exercises. For patients who underwent OCA in the patellofemoral compartment, the main difference in rehabilitation was protected ROM for the first 6 weeks. Specifically, from weeks 0 to 2, ROM was 0° to 30°; from weeks 2 to 4, ROM was 0° to 60°; and from weeks 4 to 6, ROM was restricted to 0° to 90°. Beyond 6 weeks, full ROM was encouraged. For tibiofemoral OCA, ROM started at 0° to 40° and was advanced 5° to 10° daily as tolerated. At 12 weeks, patients increased activity to include stationary cycling, elliptical training, and pool exercises. After 6 months, patients advanced to full functional activity, although sport-specific and high-impact activity was limited until 8 months.

Statistical Analysis

Statistical analysis consisted of descriptive statistics, univariate logistic regression, and survival analysis. No comparative analysis was performed between the snowman group and multifocal group because of the differing natures of the lesions. Univariate logistic regression analysis was performed to evaluate for demographic, preoperative, and operative variables for an association with failure of OCA. Kaplan-Meier survival curves were generated for each group. The analysis assumed a nonparametric distribution of time-dependent survival, similar behavior between procedures that were performed at different time points, and similar survival behavior between uncensored cases (patients who had not yet met failure criteria) and censored cases (patients who had met failure criteria). All reported *P* values are 2-tailed, with an alpha level of .05 for statistical significance (SPSS Statistics version 23.0; IBM).

RESULTS

Patient Characteristics

Of the 270 patients screened from the senior author's database, 26 patients (28 knees) met inclusion and exclusion criteria, with 22 patients (24 knees; 50% female; mean age, 31.9 ± 9.1 years) having at least 2-year clinical follow-up (85.7%). Nine patients (9 knees) who underwent isolated, condylar OCA with the snowman technique met inclusion criteria, with a mean follow-up of 7.4 ± 3.6 years. Thirteen additional patients (15 knees) who underwent multifocal OCA met inclusion criteria, with a mean follow-up of 6.4 ± 3.9 years. All 9 patients (100.0%) who underwent isolated OCA with the snowman technique involved grafts of the medial femoral condyle. Eight (53.3%) of the knees in the multifocal group received a medial femoral condylar graft and a lateral femoral condylar graft without grafts to the trochlea or patella, 1 (6.7%) patient underwent OCA with only trochlear and patellar grafts without condylar involvement, and 6 (40.0%) received a trochlear graft and a graft to at least 1 femoral condyle. There were no tibial grafts. The mean aggregate lesion size of the snowman group was 7.8 ± 1.9 cm^2, while the mean aggregate lesion size of the multifocal group was 8.5 ± 4.0 cm^2. Complete demographic, surgical history, and operative information can be found in Table 2.

Patient-Reported Outcomes

Patients who underwent snowman OCA demonstrated significant improvement from preoperatively to the time of final follow-up in the KOOS pain subscore (*P* = .043) and WOMAC overall score (*P* = .043). Patients who underwent multifocal OCA demonstrated significant improvement in the IKDC score (*P* = .010); KOOS symptoms (*P* = .025), activities of daily living (*P* = .026), sport (*P* = .026), and quality of life subscores (*P* = .005); WOMAC stiffness (*P* = .046), function (*P* = .037), and overall subscores (*P* = .047); and SF-12 physical component summary score (*P* = .011) (Table 3).

Complications

There were no intraoperative complications; however, there were 2 postoperative complications in the snowman group including a superficial infection at the surgical site that was eradicated by an antibiotic course of sulfamethoxazole/trimethoprim (n = 1) and persistent stiffness with loss of ROM 4 months after surgery that required subsequent arthroscopic lysis of adhesions (n = 1). In the multifocal group, there were 3 complications (20.0%) including a superficial infection at the surgical site that was eradicated by an antibiotic course of sulfamethoxazole/trimethoprim (n = 1), an acute hematoma requiring evacuation and washout (n = 1), and a patient who developed complex regional pain syndrome postoperatively (n = 1).

Reoperations

Reoperations were common, with 44.4% (n = 4) of the snowman group and 20.0% (n = 3) of the multifocal group undergoing at least 1 reoperation. In the snowman group, patients underwent a reoperation at a mean 4.5 ± 4.9 years. One patient underwent subchondroplasty of the medial aspect of the tibia 5.0 years after OCA of the medial femoral condyle. Another patient in the snowman group underwent second-look arthroscopic surgery with lysis of adhesions and lateral release 4.0 months after OCA. The 2 other patients underwent TKA. Three patients (20.0%) in the multifocal group underwent reoperations at a mean 1.1 ± 0.9 years, including 2 second-look arthroscopic procedures and 1 patient who underwent separate-site chondral debridement. One patient underwent second-look arthroscopic surgery after suffering a fall directly onto the surgical knee 1.1 years after OCA, and the other patients had residual pain in the knee 1.1 years after OCA. On second-look arthroscopic surgery, the patient who fell onto her surgical knee was found to have a loose piece of tibial cartilage and exposed bone in the same compartment as the OCA site that was subsequently microfractured. The patient with residual pain had no evidence of graft degeneration, only synovitis that was debrided.

Survivorship

There were 3 failures (33.3%) in the snowman group at a mean 7.7 ± 5.5 years and 1 failure (6.7%) in the multifocal group at 4.5 ± 0.0 years. All 4 knees with failed results subsequently underwent TKA. Kaplan-Meier survival analysis of patients in the snowman group revealed an estimated 2-year survival of 88.9%, 5-year survival of 88.9%, 10-year survival of 88.9%, and 11-year survival of 44.4% after accounting for censored cases; in the Kaplan-Meier survivorship estimate, any patients lost to follow-up at longer time points were excluded from the analysis at these longer time points. As a result of this, the current estimate is limited by a small number of cases and a lower rate of follow-up at longer follow-up times (Figure 4).[13,14,29]

TABLE 2
Demographic, Surgical History, and Operative Data for Patients in the Snowman and Multifocal Groups[a]

	Snowman Group	Multifocal Group
Sex, male/female	5 (55.6)/4 (44.4)	7 (46.7)/8 (53.3)
Age, y	35.9 ± 8.4	29.5 ± 8.9
Time to follow-up, y	7.4 ± 3.6	6.4 ± 3.9
Body mass index, kg/m^2	24.8 ± 3.8	27.0 ± 5.2
Symptom duration, y	1.9 ± 1.2	4.0 ± 4.1
No. of previous surgeries	2.2 ± 0.8	2.6 ± 1.7
Workers' compensation	1 (11.1)	3 (20.0)
Preoperative Kellgren-Lawrence grade[b]	1.1 ± 0.8	0.6 ± 0.8
Grade 0	2 (22.2)	8 (57.1)
Grade 1	4 (44.4)	4 (28.5)
Grade 2	3 (33.3)	2 (14.3)
Grade 3	0 (0.0)	0 (0.0)
Grade 4	0 (0.0)	0 (0.0)
Failed prior cartilage surgery	2 (22.2)	10 (66.7)
ORIF of OCD	1 (11.1)	1 (6.7)
Microfracture	1 (11.1)	6 (40.0)
ACI	0 (0.0)	0 (0.0)
DeNovo NT	0 (0.0)	1 (6.7)
OATS	0 (0.0)	2 (13.3)
No. of grafts		
2 grafts	9 (100.0)	12 (80.0)
3 grafts	0 (0.0)	2 (13.3)
4 grafts	0 (0.0)	1 (6.7)
Aggregate lesion size, cm^2	7.8 ± 1.9	8.5 ± 4.0
Major concomitant surgery	7 (77.8)	10 (66.7)
Lateral MAT	0 (0.0)	3 (20.0)
Medial MAT	4 (44.4)	1 (6.7)
HTO	1 (11.1)	1 (6.7)
Anteromedialization	0 (0.0)	2 (13.3)
Microfracture	2 (22.2)	3 (20.0)
Overall complications	2 (22.2)	3 (20.0)
Major complications[c]	1 (11.1)	1 (6.7)
Reoperations	4 (44.4)	3 (20.0)
Time to reoperation, y	4.5 ± 4.9	1.1 ± 0.9
Failure	3 (33.3)	1 (6.7)
Time to failure, y	7.7 ± 5.5	4.5 ± 0.0

[a]Values are shown as mean ± SD or n (%). ACI, autologous chondrocyte implantation; HTO, high tibial osteotomy; MAT, meniscal allograft transplantation; OATS, osteochondral autograft transplantation; OCD, osteochondritis dissecans; ORIF, open reduction internal fixation.

[b]Preoperative radiographs were not available for 1 patient (1 knee); thus, the denominator used for calculation in the multifocal group was 14 instead of 15 knees.

[c]Major complications were considered deep infections, complex regional pain syndrome, and stiffness requiring surgical lysis of adhesions.

In the snowman group, the 38-year-old male patient who underwent lysis of adhesions and lateral release had failure and underwent TKA 10.7 years after OCA. He underwent concomitant high tibial osteotomy at the time of his snowman OCA but did not suffer a complication. Another patient in the snowman group (41-year-old female) experienced failure and underwent TKA just 1.4 years after OCA but did not suffer a complication or undergo a concomitant surgical procedure at the time of OCA. The third patient in the snowman group (42-year-old female) had failure 11.1 years after OCA.

There was a single failure in the multifocal group. Kaplan-Meier survival proportions were higher, with 2-year survival of 100.0%, 5-year survival of 88.9%, and 10-year survival of 88.9% (Figure 5). The lone failed result was in a 40-year-old female patient who underwent second-look arthroscopic surgery 1.1 years after surgery, followed by TKA 4.5 years after the index procedure. She underwent bicondylar OCA with concomitant medial meniscal transplantation but did not have a complication (Table 2).

Given that there was just a single failure in the multifocal group, logistic regression analysis was performed only for the snowman group. No variables were found to be significantly different between patients who failed snowman OCA and those who did not ($P > .05$ for all). Variables evaluated included age, sex, body mass index, symptom duration (years), number of previous knee surgeries, failed prior articular cartilage procedure, concomitant surgical procedure, concomitant meniscal allograft transplantation,

TABLE 3
Patient-Reported Outcome Scores for the Snowman and Multifocal Groups[a]

	Preoperative	Postoperative	*P* Value
Snowman group			
Marx	0.00 ± 0.00	2.33 ± 0.76	.999
Lysholm	37.17 ± 3.83	66.17 ± 14.75	.138
IKDC	29.34 ± 2.54	54.14 ± 13.29	.285
KOOS pain	44.91 ± 5.51	72.62 ± 9.77	**.043**
KOOS symptoms	46.43 ± 5.30	66.33 ± 11.24	.080
KOOS ADL	56.86 ± 13.25	82.35 ± 11.09	.345
KOOS sport	17.50 ± 3.06	53.57 ± 19.35	.223
KOOS QOL	19.79 ± 7.24	49.11 ± 14.71	.104
WOMAC pain	9.17 ± 1.93	6.00 ± 2.47	.109
WOMAC stiffness	4.83 ± 0.86	2.71 ± 0.75	.068
WOMAC function	29.50 ± 9.08	12.00 ± 7.43	.345
WOMAC overall	45.17 ± 10.45	10.71 ± 6.18	**.043**
SF-12 physical	45.01 ± 3.03	41.45 ± 5.40	.686
SF-12 mental	52.61 ± 5.13	55.71 ± 7.48	.500
Multifocal group			
Marx	1.67 ± 1.60	6.13 ± 3.57	.285
Lysholm	41.83 ± 9.31	55.00 ± 13.62	.237
IKDC	32.71 ± 5.02	52.92 ± 12.55	**.010**
KOOS pain	51.48 ± 9.59	65.28 ± 10.57	.155
KOOS symptoms	56.25 ± 9.99	66.07 ± 9.47	**.025**
KOOS ADL	58.70 ± 9.47	77.21 ± 10.18	**.026**
KOOS sport	18.33 ± 9.19	40.36 ± 14.66	**.026**
KOOS QOL	11.98 ± 5.41	41.07 ± 16.16	**.005**
WOMAC pain	8.82 ± 1.81	6.07 ± 1.81	.212
WOMAC stiffness	4.00 ± 0.89	2.93 ± 0.89	**.046**
WOMAC function	28.18 ± 5.20	15.36 ± 6.79	**.037**
WOMAC overall	37.55 ± 8.73	15.93 ± 7.96	**.047**
SF-12 physical	33.62 ± 4.07	44.65 ± 5.25	**.011**
SF-12 mental	53.14 ± 5.10	55.11 ± 3.37	.859

[a]Values are shown as mean ± SD. Boldface indicates statistical significance ($P < .05$). ADL, activities of daily living; IKDC, International Knee Documentation Committee; KOOS, Knee injury and Osteoarthritis Outcome Score; QOL, quality of life; SF-12, Short Form–12; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

aggregate lesion size, and Kellgren-Lawrence grade on preoperative radiographs (Table 4).

DISCUSSION

The results from this study demonstrate that while patients who undergo snowman OCA have significant clinical improvement at midterm follow-up, the high rates of reoperation (44.4%) and failure (33.3%) after snowman OCA must be acknowledged. Patients who underwent multifocal OCA for the treatment of multicompartmental lesions had a comparatively lower reoperation rate of 20.0% and a 6.7% failure rate at midterm follow-up, commensurate with outcomes of previous published studies of OCA for the treatment of single distal femoral or patellar chondral lesions.[2,8] Additionally, patients who underwent multifocal OCA had significant improvements in the majority of patient-reported outcome measures at the time of final follow-up.

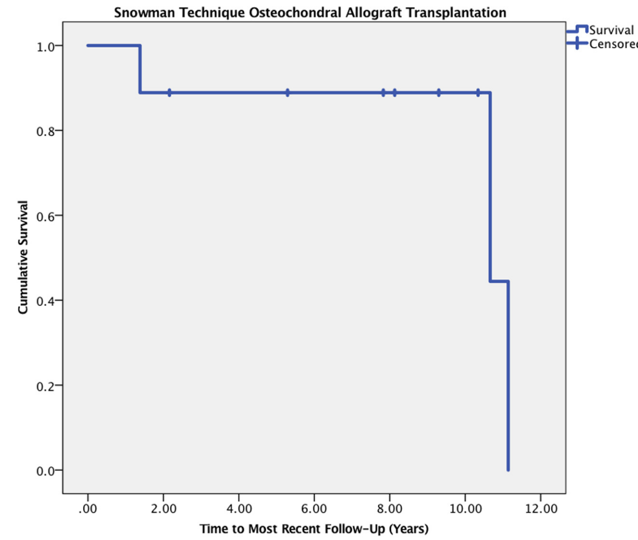

Figure 4. Kaplan-Meier survival curve for patients who underwent the snowman technique of osteochondral allograft transplantation for failed grafts. There were 3 failures at a mean time to failure of 7.7 ± 5.5 years. Survival probabilities were 88.9% at 2 years, 88.9% at 5 years, and 88.9% at 10 years.

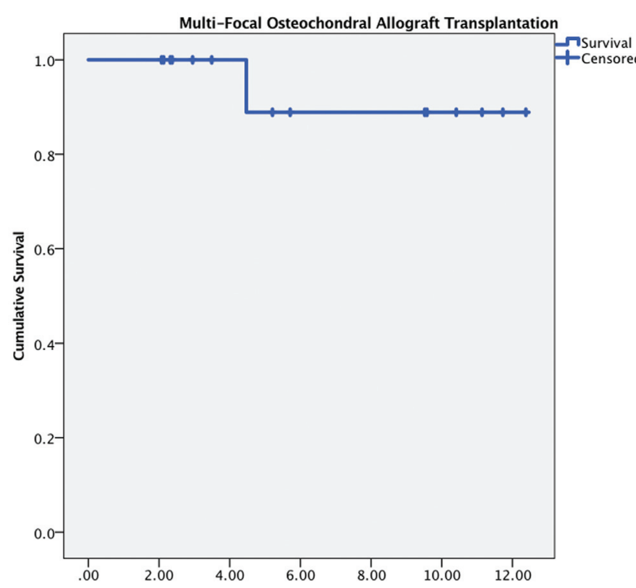

Figure 5. Kaplan-Meier survival curve for patients who underwent multifocal osteochondral allograft transplantation for failed grafts. There was a single failure at 4.5 ± 0.0 years after surgery. Survival at 2, 5, and 10 years was 100.0%, 88.9%, and 88.9%, respectively.

In an investigation of fresh OCA with the dowel technique for the treatment of chondral defects of the distal femur, Brown et al[4] evaluated clinical outcomes and osseous graft integration using computed tomography (CT) of

TABLE 4
Univariate Logistic Regression Analysis of Variables Associated With Failure of Osteochondral Allograft Transplantation With the Snowman Technique

	Odds Ratio (95% CI)	*P* Value
Age	1.19 (0.872-1.609)	.277
Sex	0.25 (0.013-4.729)	.355
Body mass index	1.41 (0.792-2.504)	.243
Symptom duration	0.76 (0.163-3.586)	.733
No. of previous knee surgeries	0.58 (0.098-3.477)	.554
Failed prior articular cartilage procedure	0.40 (0.016-10.017)	.577
Preoperative Kellgren-Lawrence grade	1.34 (0.359-5.032)	.661
Concomitant surgical procedure	1.00 (0.053-18.915)	.999
Concomitant meniscal transplantation	0.50 (0.028-8.952)	.638
Aggregate lesion size	1.01 (0.994-1.009)	.715

single versus multiple graft plugs (snowman technique) at 6-month, 1-year, and 2-year follow-up. The authors reported on 23 patients who underwent single-plug OCA and 11 patients who underwent snowman OCA; they demonstrated that at 1-year follow-up, IKDC scores were significantly greater for the single-plug group, but at 2-year follow-up, there was no significant difference between the groups. Both groups demonstrated significant improvement in the IKDC score and KOOS quality of life subscore from baseline to 2-year follow-up. Four of the 11 patients in the snowman group underwent a reoperation compared with 5 of 23 patients in the single-plug group. In addition, 2 patients in the snowman group had loose bodies as a result of significant fragmentation or cartilage delamination on CT at 6 months postoperatively compared with none in the single-plug group.[4] Their results are consistent with the results of this study, demonstrating that the snowman technique may result in improved clinical outcome scores for many patients; however, there is a relatively high reoperation rate (>35% in both studies) and inferior graft integration or survival compared with single-plug techniques for femoral lesions. While the present study did not utilize advanced postoperative imaging (ie, CT or magnetic resonance imaging) or histology, a possible explanation is the lack of an osseous bridge between grafts, as is done with original mosaicplasty. Without an osseous bridge between grafts, it is likely that fibrocartilage tissue formed and hindered, to an extent, graft integration between the 2 plugs. Given the rarity of snowman OCA procedures and thus the paucity of data, careful patient selection is essential, and even so, results may be inferior to those achieved by single-plug OCA procedures.

While few authors have analyzed clinical outcomes and failure rates of patients treated with snowman OCA and multicompartmental OCA, a significant body of literature has reported good to excellent clinical outcomes and high rates of survivorship with larger combined series of either single or combined OCA cohorts, including multifocal and snowman OCA for the treatment of distal femoral and/or patellofemoral defects.[8] Familiari et al[8] summarized the literature in a recent systematic review of clinical outcomes and failure rates of patients treated with OCA in the knee at a minimum mean 2-year follow-up. The authors reported a mean 5-year survival rate of 86.7% and mean 10-year survival rate of 78.7%.[8] There were a total of 1036 patients included from 19 studies. While many of the included studies evaluated isolated femoral condylar, trochlear, and patellar defects, the authors noted that patellar lesions and bipolar (tibiofemoral and patellofemoral) lesions had worse survival rates compared with isolated condylar outcomes. Some authors have previously reported inferior clinical outcomes of patients treated for bipolar reciprocal osteochondral lesions in the knee (tibiofemoral or patellofemoral) with unipolar, isolated OCA.[15,26] In a study of 48 knees in 46 patients at a mean 7-year follow-up (14 patellofemoral and 34 tibiofemoral), Meric et al[26] demonstrated overall survival rates after bipolar OCA of 64.1% at 5 years and just 39% at 10 years. A total of 22 knees (46%) were considered failures. While the authors did not perform subanalysis between those patients with patellofemoral disease and those with tibiofemoral disease, they noted that the allograft size was significant greater for those who failed compared with those who did not.[26] In contrast, a recent publication by Hannon et al[20] compared patients treated with femoral condylar OCA who had bipolar tibial defects that were either debrided (group 1) or microfractured (group 2) and compared them with a third group of sex-, body mass index–, laterality-, and graft size–matched controls who underwent isolated femoral condylar OCA without concomitant tibial defects. The authors demonstrated statistically significant and clinically meaningful improvements in validated patient-reported outcome measures at a minimum 2-year follow-up, with no significant differences between the 3 groups. In addition, they reported 85% graft survival for group 1 at 4.5 years, 100% for group 2 at 2.5 years, and 95% for group 3 at 3.8 years. The authors did not state precisely when patients failed, making it difficult to comment on short-term failure rates between groups. While the present study did not evaluate patients who underwent bipolar OCA, that is, OCA of both the femoral condyle and the tibia, our study suggests that multifocal OCA may be a more effective treatment option if the osteochondral defects are not bipolar in nature. One possible explanation for this finding is that with bipolar chondral lesions, 2 newly repaired or restored articular cartilage surfaces are articulating in contrast to multifocal OCA in our study in which the tibial side of the knee was found to be intact and thus only 1 side of the articulation had to heal.

Although this is a small case series, the number of patients treated with snowman OCA and multifocal OCA is relatively large given the rarity of these procedures. In addition, a strength of this study is the long follow-up of these patients with prospectively collected data, allowing for a better understanding of the midterm clinical efficacy of these techniques. This information can be used to help counsel patients who may have oblong, irregular, or multicompartmental articular cartilage lesions of the distal femur and/or patella and continue to stimulate further research and innovation into technologies.

Limitations

There are several limitations of this study, including the inherent limitations of the retrospective study design. This study has a small sample size, and thus, the univariate regression analysis is underpowered. There were no control patients within the present study with whom to directly compare; instead, previously published data served as the comparison groups. All patients in the snowman group were treated with OCA in the medial femoral condyle. In contrast, patients in the multifocal group had diversity in the location of grafts including bicondylar lesions, condylar lesions in conjunction with patellofemoral lesions, and a single bipolar patellofemoral chondral lesion. Many patients in each group underwent concomitant procedures that may have affected patient outcomes. However, as others have previously reported,[12,21,31] it is not uncommon for patients with large chondral or osteochondral lesions to have additional abnormalities such as malalignment, maltracking of the patella, ligamentous instability, and/or meniscal tears or deficiency, which is thus challenging to control for. Further, postoperative imaging including radiography and magnetic resonance imaging was not performed on all patients and was not able to be included in the analysis. Finally, we did not believe that direct statistical comparisons between these groups were appropriate as they are likely 2 different patient subsets. The abnormality of larger, oblong medial femoral condylar lesions is not the same as multifocal chondral injuries.

CONCLUSION

Patients who underwent unicondylar, multiplug OCA using the snowman technique demonstrated inferior clinical outcomes, higher reoperation rates, and greater failure rates than those who underwent isolated single-graft OCA. By contrast, multifocal OCA may be a viable knee preservation technique for young, active patients with multicompartmental chondral disease, leading to improved clinical outcomes and low reoperation and failure rates at midterm follow-up. Emerging techniques that include instrumentation to create oval grafts in which a single graft can be made to treat the same lesion configurations previously used for snowman grafting provide an alternative that might be associated with lower reoperation rates, but this will need to be demonstrated through further clinical study.

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