PODCAST 5-in-5

Comparison of Snowman and Single-Plug Circular Osteochondral Allograft Transplantation Techniques for Similarly Sized Defects

A Matched Cohort Analysis

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Background: Multiplug ''snowman'' osteochondral allograft transplantation (OCA) is an effective treatment method for large, irregularly shaped osteochondral defects of the knee. No existing literature directly compares the effectiveness of this technique with traditional single-plug circular OCA.

Purpose: To compare failure rates, reoperation rates, and relevant patient-reported outcome (PRO) scores at 2-year follow-up between patients undergoing snowman OCA and patients undergoing single-plug OCA.

Study Design: Case series; Level of evidence, 3.

Methods: Patients who underwent snowman or single-plug OCA between 2001 and 2021 with a minimum 2-year follow-up were identified. Propensity score matching at 1:2 was performed based on age, sex, body mass index, defect location, and defect size. The PRO measures assessed included the International Knee Documentation Committee subjective score, Lysholm score, Knee Injury and Osteoarthritis Outcome Score, and 12-Item Short Form Health Survey. Failure was defined as conversion to arthroplasty, revision OCA, or graft degeneration on second-look arthroscopic examination. Additionally, rates of achieving the minimal clinically important difference (MCID) or patient acceptable symptom state (PASS) for PRO measures were determined.

Results: There were 26 patients (mean age, 33.3 ± 9.3 years; 65.4% male) who underwent snowman OCA with a mean follow-up of 5.8 ± 4.1 years. No significant differences in baseline variables were identified compared with a matched control group of 52 patients who underwent single-plug OCA. No differences were detected in the rate of achieving the MCID or PASS between the groups for any PRO measure. Overall, 5 patients (19.2%) in the snowman group experienced graft failure at a mean 1.7 ± 1.0 years, while 10 patients (19.2%) in the single-plug group met the criteria for failure at a mean 6.6 ± 3.5 years. No differences were detected in the rate of failure or reoperations between the 2 groups.

Conclusion: Multiplug ''snowman'' and single-plug circular OCA techniques yielded comparable clinical outcomes and graft survivorship for defects of a similar size in a matched cohort analysis. Defect shape, rather than size alone, should guide the selection of a technique. The snowman technique is advantageous for longer or oval-shaped defects not easily treated with a single plug, as it minimizes the removal of healthy cartilage while maintaining optimal outcomes.

Keywords: osteochondral allograft; snowman; cartilage repair; matched cohort

Articular cartilage injuries in the knee are common and can significantly affect a patient's quality of life, leading to pain, reduced function, and early-onset osteoarthritis.[11,12] Cartilage has poor inherent regenerative ability, and degenerative chondral or osteochondral lesions often deteriorate with time. A number of treatment modalities exist, from palliative treatment options such as debridement to more aggressive cartilage repair.[13,14] Osteochondral allograft transplantation (OCA) has emerged as a valuable treatment option for large (≥2 cm^2) cartilage defects in the knee, offering a biological solution to restore joint function and alleviate pain.[2]

The multiplug, or "snowman," technique has been developed to address the limitations of traditional single-plug grafts when treating irregularly shaped or elongated

The American Journal of Sports Medicine
2025;53(10):2423–2431
DOI: 10.1177/03635465251352172

defects.[6] The size and geometry of these lesions often preclude the use of standard circular osteochondral allograft plugs, which may result in incomplete coverage or suboptimal congruence with surrounding cartilage.[17] The snowman technique utilizes 2 overlapping circular grafts to create a figure-of-8 or snowman-shaped construct. However, recent studies have shown that while the snowman technique demonstrates improved patient-reported outcome (PRO) scores at short-term follow-up, it may present relatively higher rates of revision compared with the single-plug technique.[4,8]

An alternative approach for treating oval-shaped lesions is the BioUni instrumentation system (Arthrex), which utilizes a single oval-shaped graft to match the contour of the defect more closely. A comparative study of oval plugs and the snowman technique for ovoid lesions found that both methods demonstrated improved PRO scores at short-term follow-up, with no significant differences between the 2 approaches.[4] Recent comparative studies have begun to shed light on the relative merits of different OCA approaches. A study examining the outcomes of single- versus multiple-plug OCA found no significant difference in PRO scores between the 2 groups at short-term follow-up.[16] However, another study analyzing overlapping grafts and multifocal lesions demonstrated inferior clinical outcomes, higher reoperation rates, and increased failure rates in patients who underwent unicondylar, multiplug OCA using the snowman technique.[6] The management of failed cartilage repair presents additional challenges, often involving larger defects and subchondral bone involvement. In such cases, the use of multiple overlapping plugs might be considered. For the purpose of this study, single-plug osteochondral allografts refer solely to circular grafts.

The aim of this study was to compare clinical outcomes between snowman OCA and single-plug circular OCA for the treatment of large cartilage defects. We hypothesized that PRO scores, reoperation rates, and failure rates would be comparable between patients treated with snowman OCA or single-plug OCA.

METHODS

Patient Population

A retrospective review was conducted using a prospectively collected database from a single institution. Patients who underwent snowman OCA between January 1, 2001 and January 1, 2021 were identified. Before study initiation, approval was obtained from the local institutional review board (ORA#: 23072402-IRB01). Patients were included regardless of the presence of concomitant procedures. Inclusion criteria consisted of (1) snowman OCA and (2) minimum 2-year follow-up. We included both distal femoral condylar and patellofemoral osteochondral allografts. Patients were excluded if they had lumbar spinal abnormalities causing referred pain to the knee. Patients from our institution who underwent single-plug circular OCA with a minimum 2-year follow-up between January 1, 2001 and January 1, 2021 were used as a matched control group (n = 314). Matching was conducted using a 1:2 nearest neighbor matching algorithm without replacement.[3] Age, body mass index (BMI), defect location, and lesion size were used as parameters for matching.

Outcome Measures

PRO measures included the International Knee Documentation Committee (IKDC) subjective score, Lysholm score, Knee Injury and Osteoarthritis Outcome Score (KOOS), and 12-Item Short Form Health Survey (SF-12) physical component summary (PCS) and mental component summary (MCS). These questionnaires were administered to patients preoperatively and at 2 years postoperatively. Reoperation was defined as any subsequent surgical intervention on the knee with the transplanted osteochondral allograft. Failure was defined as a revision cartilage restoration procedure, conversion to knee arthroplasty, or graft delamination on second-look arthroscopic examination. The number of patients who achieved the minimal clinically important difference (MCID) for PRO measures was determined. The MCID was calculated using a distribution-based method, defined as half the standard deviation of the change between preoperative and postoperative values.[5] We also calculated the percentage of patients who met the patient acceptable symptom state (PASS) at 2 years using previously reported values of the PASS for the IKDC, Lysholm, and KOOS in cartilage repair.[1]

Surgical Technique

All surgical procedures were performed by the senior author (B.J.C.), a sports medicine fellowship–trained orthopaedic surgeon at a single institution. The senior author's technique for OCA of the knee has been previously described.[9,10] Fresh size-matched grafts were used. Same-condyle grafts were used whenever possible. A commercial graft harvesting and sizing system (Arthrex) was utilized. Under general anesthesia, patients were positioned supine

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Submitted January 18, 2025; accepted May 1, 2025.

One or more of the authors has declared the following potential conflict of interest or source of funding: B.J.C. has received research support from Aesculap/B. Braun, Arthrex, and MediPost; royalties from Arthrex and Elsevier; and financial or material support from JRF Ortho; and holds stock or stock options in BandGrip and Ossio. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

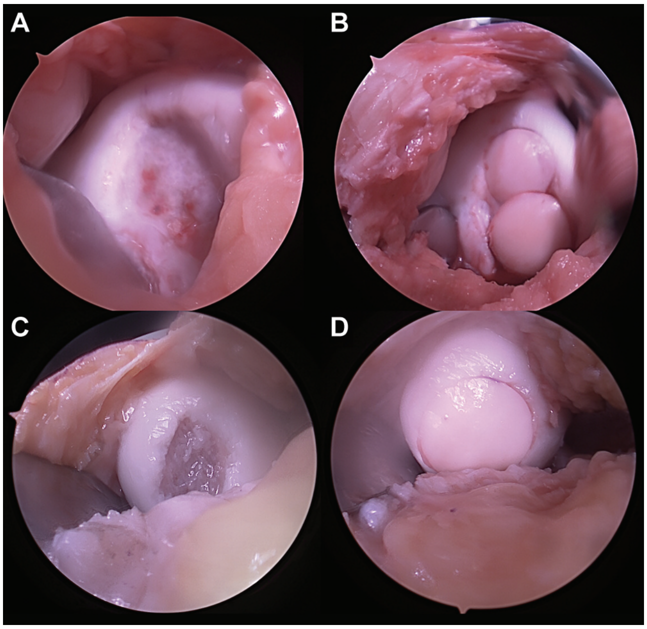

Figure 1. (Top) Intraoperative images demonstrating the snowman osteochondral allograft transplantation (OCA) technique for (A) a medial femoral condylar defect using (B) 18 mm diameter and 20 mm diameter plugs in a 19-year-old male patient. (Bottom) Intraoperative images demonstrating the single-plug circular OCA technique for (C) a lateral femoral condylar defect using (D) a 15 × 15 plug in a 29-year-old male patient.

on the operating table. Before transplantation, staging arthroscopic surgery was conducted to assess the extent of chondral disease and any concomitant abnormalities. Any concomitant procedures such as meniscectomy, meniscal allograft transplantation (MAT), ligamentous reconstruction, or osteotomy were performed first. To assess the lesion, parapatellar mini-arthrotomy was performed for optimal exposure of the defect. Appropriately sized allograft plugs were then placed in room-temperature saline on the back table. A cylindrical sizing guide was placed on the defect to determine the graft diameter, and a guide pin was drilled through the sizing guide into the correct location. The sizing guide was then removed, and a bone reamer was placed over the guide pin to ream to a depth of 6 to 8 mm. Depth measurements were taken at the 12-, 3-, 6-, and 9-o'clock positions (Figure 1). The donor allograft was then prepared, and a donor harvester was used to create an allograft that matched the reamed diameter. A sagittal saw was used to cut the allograft to the measured depth, which generally included less than 6 mm of subchondral bone. The graft was pulse lavaged with saline to remove marrow elements. The plug was then press-fit into place. At this point, the process was repeated with a second plug to cover the remaining lesion area. The lesion was reamed again, intersecting a portion of the original plug and addressing what remained of the defect. Once again, depth measurements were taken, and the allograft of an appropriate depth and diameter was press-fit into place. Additional mechanical fixation with bioabsorbable screws was performed in a minority of cases when indicated. After irrigation, the arthrotomy site was closed, followed by appropriate closure of subcutaneous tissue and skin as well as the removal of dressing.

Rehabilitation Protocol

For the first 6 weeks postoperatively, patients were instructed to follow heel-touch weightbearing. Patients had regularly scheduled follow-up visits at 2 weeks, 6 to 8 weeks, and 6 months postoperatively. Patients wore a hinged knee brace locked in full extension that was only removed for exercise and physical therapy. Braces were discontinued at 2 weeks to allow for progressive increases in range of motion. Exercises were advanced as tolerated to allow for quadriceps sets, patellar mobilization, calf pumps, and straight-leg raises. Weightbearing was advanced as tolerated beginning at 6 weeks postoperatively, and patients were expected to achieve full weightbearing by 8 weeks. At this point, activities were advanced to include gait training and closed kinetic chain exercises. At 12 weeks, activities increased to include elliptical cycling and swimming. At 6 to 12 months, a gradual return to functional activity was permitted. High-impact and athletic activities were limited until 8 months. Follow-up imaging was performed at the surgeon's discretion.

Statistical Analysis

Statistical analysis was performed with R (Version 4.4.1), RStudio (2024.04.2, Build 764; Posit), and Excel (Version 2502; Microsoft). Categorical variables were reported as frequencies and proportions, and continuous variables were reported as means with standard deviations. The chi-square test or Fisher exact test was used for comparing categorical variables when appropriate. For continuous variables, normality was assessed with the Shapiro-Wilk test. The independent-samples t test or Mann-Whitney U test was used accordingly for comparisons depending on data normality. Kaplan-Meier curves were constructed for each group for time to graft failure or a reoperation, and differences between groups were evaluated with the log-rank and Wilcoxon tests.

G*Power (Version 3.1.9.7) was used to ensure that this study was adequately powered to detect a difference in clinically significant outcomes and failure rates. We used a previously reported MCID value of 17 at 2 years and a postoperative standard deviation of 18.9 for the IKDC score in OCA.[15,18] For an a priori power analysis, with an alpha of .05, a desired power of 0.80, and an allocation ratio of 1:2 using a 2-tailed t test, a sample size of 36 (12 in group 1 and 24 in group 2) would be adequate to detect this difference. Cotter et al[6] compared snowman OCA for large unicondylar lesions to multifocal OCA for multicompartmental chondral defects and found a higher rate of failure in the snowman group (33.3% vs 6.7%, respectively). With an alpha of .05, a desired power of 0.80, and an allocation ratio of 1:2 using a 1-tailed Fisher exact test, a sample size

TABLE 1
Patient and Intraoperative Characteristics[a]

	Snowman OCA (n = 26)	Single-Plug OCA (n = 52)	*P* Value
Sex			.867[b]
Female	9 (34.6)	19 (36.5)	
Male	17 (65.4)	33 (63.5)	
Age, y	33.3 ± 9.3	33.0 ± 11.4	.913[c]
BMI, kg/m^2	25.3 ± 3.7	25.5 ± 4.1	.895[d]
Laterality			.747[b]
Left	15 (57.7)	28 (53.8)	
Right	11 (42.3)	24 (46.2)	
Known traumatic cause	10 (38.5)	22 (42.3)	0.832[b]
Smoking status			>.999[e]
Current	3 (11.5)	5 (9.6)	
Former	0 (0.0)	1 (1.9)	
Never/unknown	23 (88.5)	46 (88.5)	
Known workers' compensation status	4 (15.4)	9 (17.3)	>.999[e]
Defect location			
MFC	18 (69.2)	34 (65.4)	.734[b]
LFC	4 (15.4)	14 (26.9)	.393[e]
Trochlea	2 (7.7)	1 (1.9)	.256[e]
Patella	2 (7.7)	3 (5.8)	>.999[e]
Defect size, cm^2			
MFC	5.5 ± 2.5	5.5 ± 1.5	.580[d]
LFC	5.2 ± 4.6	4.6 ± 1.9	.448[d]
Trochlea	3.1 ± 1.1	4.3 ± 2.3	.321[c]
Patella	4.0 ± 0.0	4.5 ± 2.0	.756[c]
No. of previous surgical procedures	2.5 ± 1.5	2.8 ± 1.4	.288[d]
Follow-up, y	5.8 ± 4.1	5.7 ± 2.8	.528[d]

[a]Data are presented as n (%) or mean ± SD. BMI, body mass index; LFC, lateral femoral condyle; MFC, medial femoral condyle; OCA, osteochondral allograft transplantation.
[b]Chi-square test.
[c]Independent-samples *t* test.
[d]Mann-Whitney *U* test.
[e]Fisher exact test.

of 69 (23 in group 1 and 46 in group 2) would be adequate to detect a similar difference in failure rates.

RESULTS

Patient Characteristics

A total of 28 eligible patients undergoing snowman OCA were identified, and 26 met all inclusion criteria. One patient was excluded because of a significant spinal abnormality that caused referred pain to the knee, confounding the primary outcome measure. Of the remaining patients, an additional patient had less than 2 years' follow-up and was excluded (96.2% follow-up rate). The mean follow-up was 5.8 ± 4.1 years. The mean age at the time of surgery was 33.3 ± 9.3 years, and the mean BMI was 25.3 ± 3.7 kg/m^2 (Table 1). Overall, 9 patients (34.6%) were female, and 17 (65.4%) were male. Further, 52 patients who underwent single-plug OCA with a mean follow-up of 5.7 ± 2.8 years were used as the control group and matched based on age, sex, BMI, lesion size, and lesion location. Relevant variables for the 2 groups are listed in Table 1.

Within the snowman group, 13 patients (50.0%) underwent a major concomitant procedure compared with 34 patients (65.4%) in the single-plug group. The most common concomitant procedure was MAT. Overall, 3 patients (11.5%) underwent lateral MAT and 4 patients (15.4%) underwent medial MAT in the snowman group, while 10 (19.2%) and 17 (32.7%) underwent lateral and medial MAT, respectively, in the single-plug group (Table 2). No patients in the snowman group and 4 patients (7.7%) in the single-plug group underwent additional bioabsorbable screw fixation.

PRO Scores

There were 25 patients (96.2%) in the snowman group and 30 patients (57.7%) in the control group who had available preoperative PRO scores. There were no significant differences in any preoperative PRO scores between the groups. Additionally, 20 patients (76.9%) and 30 patients (57.7%) in the snowman and control groups, respectively, had available 2-year postoperative PRO scores. We found significant increases ($P < .05$) in all PRO scores in both groups between the preoperative and 2-year postoperative time points, apart from the SF-12 MCS score (Figure 2).

TABLE 2
Concomitant Procedures[a]

	Snowman OCA (n = 26)	Single-Plug OCA (n = 52)	P Value
Major concomitant procedure[b]	13 (50.0)	34 (65.4)	.191[c]
Ligament repair or reconstruction	0 (0.0)	1 (1.9)	>.999[d]
Lateral MAT	3 (11.5)	10 (19.2)	.526[d]
Medial MAT	4 (15.4)	17 (32.7)	.104[c]
High tibial osteotomy	5 (19.2)	6 (11.5)	.357[c]
Distal femoral osteotomy	0 (0.0)	4 (7.7)	.295[d]
Anteromedialization of tibial tubercle	3 (11.5)	1 (1.9)	.105[d]
Microfracture	0 (0.0)	5 (9.6)	.163[d]
Bone marrow aspirate concentrate	4 (15.4)	3 (5.8)	.213[d]
Platelet-rich plasma	1 (3.8)	1 (1.9)	>.999[d]

[a]Data are presented as n (%). MAT, meniscal allograft transplantation; OCA, osteochondral allograft transplantation.
[b]A major concomitant procedure was defined as any of the listed procedures, apart from bone marrow aspirate concentrate and platelet-rich plasma.
[c]Chi-square test.
[d]Fisher exact test.

There was no significant difference in any 2-year postoperative PRO scores between the snowman and control groups (Table 3). We found no significant difference when comparing the mean change between preoperative and postoperative PRO scores. We also found no significant difference in the rate of achieving the MCID or PASS between groups.

Reoperations and Failure

A total of 10 patients (38.5%) in the snowman group required a reoperation at a mean of 4.4 ± 3.6 years. There were 7 cases of second-look arthroscopic examination with or without minor debridement/loose body removal for continued symptoms, 1 case of revision OCA, 1 case of revision lateral MAT, 1 case of total knee arthroplasty, and 1 case of meniscectomy. An additional 2 patients needed a reoperation for hardware removal, but they were not included in analysis. There were 5 patients (19.2%) in the snowman group who experienced graft failure at a mean follow-up of 1.7 ± 1.0 years, including 1 case of total knee arthroplasty, 1 case of revision OCA, and 3 cases of delamination found on second-look arthroscopic examination.

Overall, 19 patients (36.5%) in the single-plug group underwent a reoperation at a mean of 3.0 ± 2.9 years, most commonly arthroscopic surgery with minor articular cartilage debridement. Specifically, 15 patients (28.8%) underwent second-look arthroscopic examination. There were 10 patients (19.2%) in the single-plug group who experienced graft failure at a mean of 6.6 ± 3.5 years: 4 cases of total knee arthroplasty, 3 cases of revision OCA, and 4 cases of delamination found on second-look arthroscopic examination. No significant differences were found for reoperation or failure rates between the groups (P = .868 for reoperation; $P > .999$ for failure).

Kaplan-Meier curves were constructed to demonstrate differences in the time to a reoperation (Figure 3) and failure (Figure 4). We found no significant difference in time-dependent graft survival between the 2 groups with either the log-rank test (P = .939) or Wilcoxon test (P = .200). Similarly, repeating the analysis for reoperations, we found no significant differences between the 2 groups with the log-rank test (P = .755) or Wilcoxon test (P = .840).

DISCUSSION

Snowman OCA was an effective treatment method for large, irregularly shaped cartilage lesions of the knee. Our study demonstrates that compared with single-plug OCA, snowman OCA had similar rates of failure, reoperations, and achievement of clinically significant outcomes at 2-year follow-up. Both groups demonstrated significant postoperative improvements in IKDC, Lysholm, KOOS, and SF-12 PCS scores. There were no differences between final postoperative scores or the mean change between preoperative and postoperative scores. No difference was observed for the failure or reoperation rates between groups.

Multiple studies have compared clinical outcomes between variations of osteochondral allograft plug placement, although with differing focuses. Retzky et al[16] compared 30 patients who underwent single-plug OCA with 30 patients who underwent multiple-plug OCA at a minimum follow-up of 1 year, with only 5 (17%) in the multiplug group receiving the snowman technique. Both groups demonstrated significant improvements in PRO scores, with no significant differences in outcomes or the achievement of previously reported MCID values. The present study reaffirms this noninferiority result, as the snowman group did not have inferior clinical outcomes compared with the matched single-plug group. In contrast, Cotter et al[6] compared snowman OCA for large unicondylar lesions at a mean follow-up of 7.4 years (range, 1.4-11.1 years) to multifocal OCA for multicompartmental chondral defects. The authors found inferior outcomes in the snowman group, including higher failure (33.3% vs 6.7%, respectively) and reoperation (44.4% vs 20%, respectively) rates.

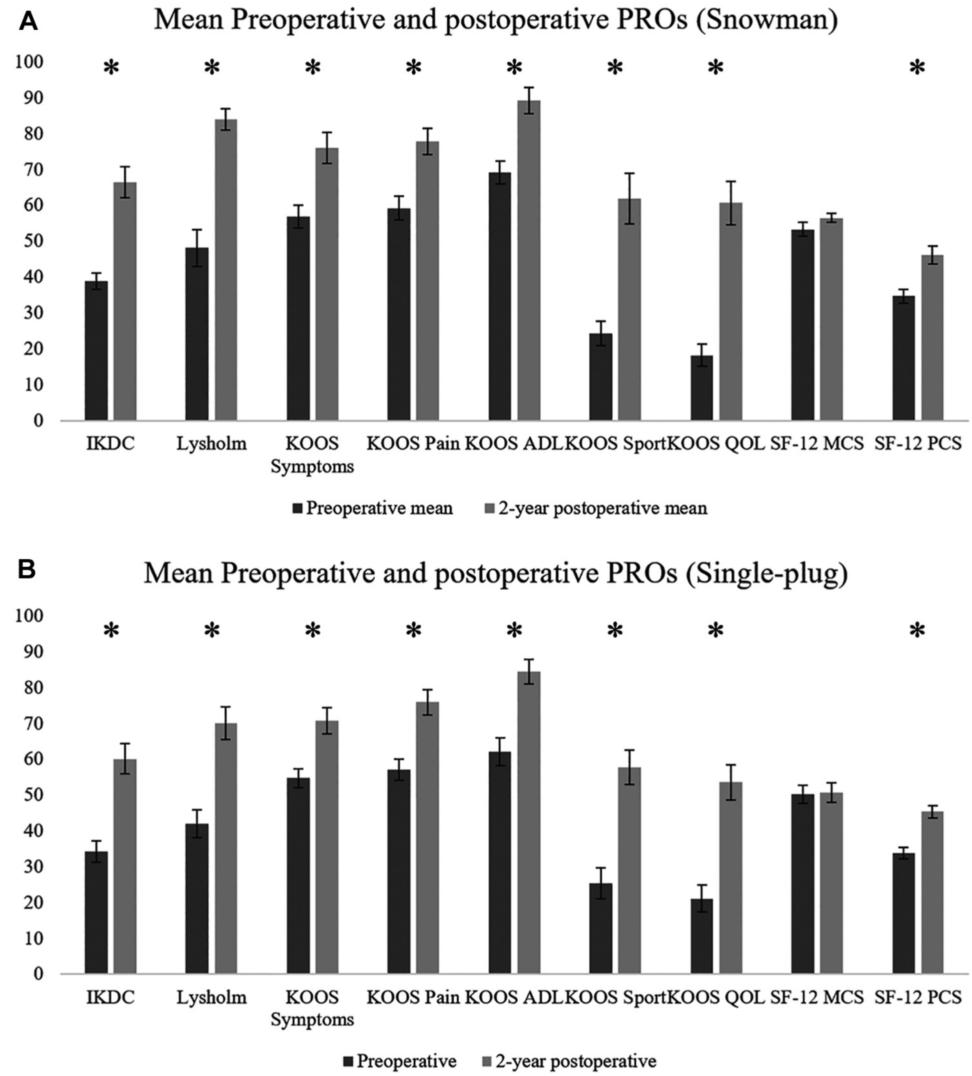

Figure 2. Mean preoperative and 2-year postoperative scores for the (A) snowman and (B) single-plug groups. Error bars indicate standard error of the mean. ADL, Activities of Daily Living; IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; MCS, mental component summary; PCS, physical component summary; QOL, Quality of Life; SF-12, 12-Item Short Form Health Survey. *Statistically significant difference. Significance ($P < .05$) was determined by the paired t test or Mann-Whitney U test, depending on the normality of the data.

The present study found no statistically significant differences in failure rates, reoperation rates, or clinically significant improvements between the snowman and single-plug groups. The difference between studies is likely because of the matching process utilized, a significantly larger sample size, and a minimum 2-year follow-up.

It is also important to consider the oval-plug cartilage replacement technique in comparison to snowman OCA. Unlike the snowman technique, which uses multiple adjacent or overlapping plugs, the oval-plug technique employs a single continuous oblong plug to treat irregular lesions that cannot be covered by a single circular graft. Coladonato et al[4] compared these techniques, with 5 patients receiving an oval plug and 23 undergoing snowman OCA, and reported improved PRO scores in both groups at a mean follow-up of 2.77 years, with no significant differences between the 2 groups. However, Dwivedi et al[7] demonstrated in a biomechanical porcine model that oblong single-plug grafts had significantly lower pull-out strength (65.7 N) compared with both large cylindrical single plugs (133 N) and the multiple-plug snowman configuration (117.6 N), although initial biomechanical stability may not necessarily correlate with clinical outcomes. Additionally, a study comparing 1-year magnetic resonance imaging outcomes using the OCAMRISS (Osteochondral Allograft Magnetic Resonance Imaging Scoring System) found no significant differences in bone, cartilage, or total scores between elliptical, stacked (snowman), and single-plug OCA techniques.[19] While there was a trend toward higher osseous integration with single plugs compared

TABLE 3
Outcomes at 2 Years[a]

	Outcome Score		MCID			PASS		
	Mean ± SD	*P* Value	Value	Achievement Rate, %	*P* Value	Value	Achievement Rate, %	*P* Value
IKDC								
Snowman	66.5 ± 18.7	.649[b]	11.7	83.3	.290[c]	62.1	50.0	>.999[c]
Single-plug	60.2 ± 23.3			66.7			51.6	
Lysholm								
Snowman	84.1 ± 10.3	.115[d]	10.1	100.0	.115[c]	70.0	83.3	.165[c]
Single-plug	70.1 ± 24.4			64.3			58.6	
KOOS Symptoms								
Snowman	76.0 ± 18.4	.625[b]	9.2	70.6	.518[c]	71.5	61.1	.554[c]
Single-plug	70.8 ± 20.2			59.1			48.4	
KOOS Pain								
Snowman	77.8 ± 15.5	.909[d]	10.1	64.7	.268[c]	72.2	66.7	.550[c]
Single-plug	76.0 ± 19.6			84.0			54.8	
KOOS ADL								
Snowman	89.2 ± 15.4	.515[d]	9.8	82.4	.707[c]	86.8	72.2	.548[c]
Single-plug	84.6 ± 19.4			73.9			62.5	
KOOS Sport								
Snowman	61.9 ± 29.8	.939[b]	15.8	64.7	.744[c]	43.8	66.7	.759[c]
Single-plug	57.8 ± 26.9			57.1			71.0	
KOOS QOL								
Snowman	60.8 ± 25.6	.734[d]	15.6	76.5	.505[c]	50.0	66.7	>.999[c]
Single-plug	53.6 ± 27.8			65.2			65.6	
SF-12 MCS[e]								
Snowman	56.6 ± 5.0	.249[d]	5.8	31.3	.716[c]			
Single-plug	50.7 ± 13.5			43.8				
SF-12 PCS[e]								
Snowman	46.2 ± 10.4	.828[d]	6.0	56.3	.481[c]			
Single-plug	45.4 ± 8.7			70.6				

[a]ADL, Activities of Daily Living; IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; MCID, minimal clinically important difference; MCS, mental component summary; PASS, patient acceptable symptom state; PCS, physical component summary; QOL, Quality of Life; SF-12, 12-Item Short Form Health Survey.
[b]Independent-samples *t* test.
[c]Fisher exact test.
[d]Mann-Whitney *U* test.
[e]PASS data not available.

with the elliptical and stacked configurations, these differences did not reach statistical significance. We did not analyze the oval-plug technique in this study; only the snowman technique was used. Further clinical research with larger sample sizes and extended follow-up periods will be essential to determine the midterm and long-term clinical significance of the oblong single-plug technique. Future investigation may also include larger studies comparing clinical outcomes directly between snowman OCA and oval-plug OCA.

Although the rates of failure were similar, on primary inspection, there seemed to be a substantial difference in the time to graft failure between the 2 groups; while the snowman group had failure at a mean 1.7 ± 1.0 years, the control group experienced failure at 6.6 ± 3.5 years. However, a survival analysis demonstrated no significant difference between groups. We found no significant difference in the time to failure with either the log-rank test (P = .939) or Wilcoxon test (P = .200). Both statistical tests compared survival distributions between groups, but whereas the log-rank test weighed failure times equally, the Wilcoxon test placed greater weight on earlier failure. We performed the Wilcoxon test to further evaluate this discrepancy, and despite focusing on the early portion of the curve, the imbalance was not enough to reach statistical significance. Nonetheless, this specific point warrants further investigation.

Our study demonstrates that snowman OCA achieved clinical outcomes, reoperation rates, and graft survivorship comparable with single-plug OCA for similarly sized defects, adding to the growing body of evidence guiding cartilage restoration strategies. While previous research has varied in focus and results, further investigation is warranted to strengthen conclusions in this area. Nevertheless, our findings support snowman OCA as a viable and effective option for addressing large, irregular osteochondral defects for which a single-plug approach might require the excessive removal of healthy cartilage.

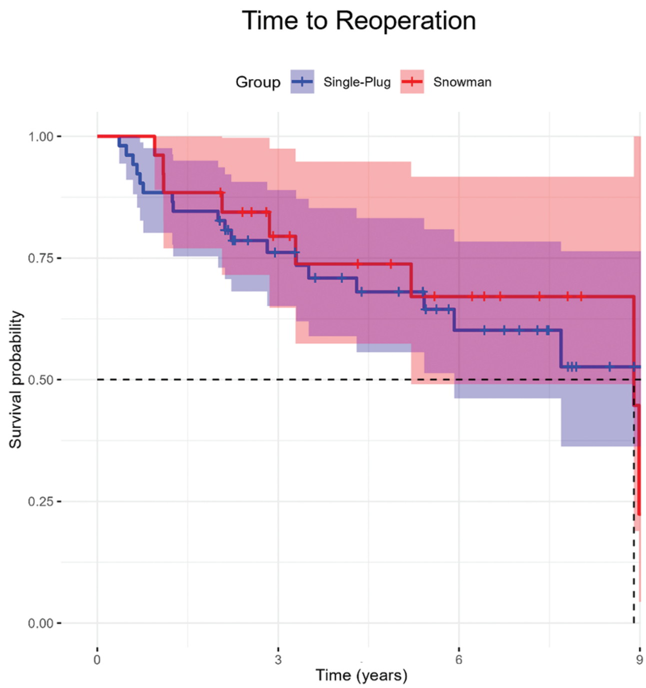

Figure 3. Kaplan-Meier curves for time to a reoperation between the snowman (n = 26) and single-plug (n = 52) groups. Vertical tick marks indicate censored observations, and shaded areas represent 95% confidence intervals.

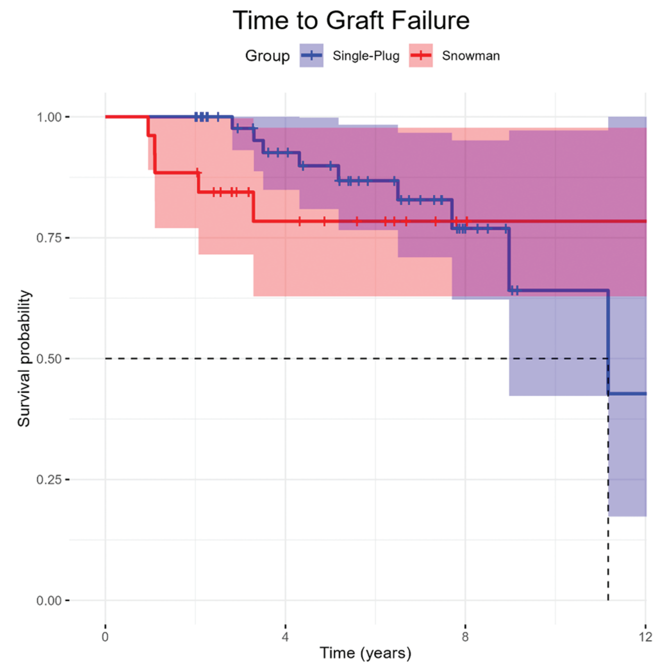

Figure 4. Kaplan-Meier curves for time to graft failure between the snowman (n = 26) and single-plug (n = 52) groups. Vertical tick marks indicate censored observations, and shaded areas represent 95% confidence intervals.

Limitations

Several limitations of this study should be acknowledged. The retrospective nature of the study introduces the risk of selection and recall bias. In addition, the matching process is inherently limited by the available data. Although we had a large database to draw matches from, and we did not find a significant difference between patient and intraoperative characteristics, there are subtle differences between patient populations that matching is unable to adequately control for, introducing a source of bias. Additionally, a substantial number of patients in our control group were missing preoperative PRO scores, complicating the MCID analysis. In addition, we did not include data on postoperative imaging because this was not consistently performed in all patients. We also did not include detailed data on the amount of healthy cartilage removed or damaged cartilage remaining for irregularly shaped defects in either group. On the basis of our power analysis, our sample size was adequate to detect a difference in absolute failure rates. However, while we did not find any difference in time-dependent survival, we cannot say for certain that we were adequately powered to detect time to failure. A larger sample size may be needed to elucidate whether time to failure differed between groups and whether these studies are applicable to a broader patient population. Additionally, the generalizability of this study is affected by the fact that this only covered the outcomes of a single surgeon at a single institution.

CONCLUSION

Multiplug "snowman" and single-plug circular OCA techniques yielded comparable clinical outcomes and graft survivorship for defects of a similar size in a matched cohort analysis. Defect shape, rather than size alone, should guide the selection of a technique. The snowman technique is advantageous for longer or oval-shaped defects not easily treated with a single plug, as it minimizes the removal of healthy cartilage while maintaining optimal outcomes.

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