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Outcomes After Osteochondral Allograft Transplantation of the Medial Femoral Condyle in Patients With Varus and Nonvarus Alignment

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Background: Fresh osteochondral allograft (OCA) transplantation is an effective technique for the treatment of focal chondral and osteochondral defects in the knee. Coronal-plane malalignment leads to increased contact forces within a compartment and subsequently the cartilage repair site and may lead to higher failure rates. However, the magnitude of the effect of coronal-plane malalignment on graft survivorship and clinical outcomes has not been well characterized.

Purpose: To evaluate how varus malalignment affects graft survival and patient-reported outcomes after isolated OCA transplantation of the medial femoral condyle (MFC).

Study Design: Cohort study; Level of evidence, 3.

Methods: A total of 70 patients (74 knees) who underwent primary OCA transplantation of the MFC between 2005 and 2019 were identified from a prospectively collected single-surgeon cartilage registry with a minimum 2-year follow-up. Coronal-plane alignment was evaluated utilizing standing hip-to-ankle radiographs. OCA failure, defined as removal of the graft or conversion to arthroplasty, and reoperations were recorded. Patient-reported outcomes were obtained preoperatively and postoperatively using the International Knee Documentation Committee score, Knee injury and Osteoarthritis Outcome Score, modified Merle d'Aubigné–Postel score, and overall patient satisfaction score.

Results: The mean mechanical tibiofemoral angle for patients with varus alignment was 3.9° of varus (range, 1.1° to 8.9°) and for patients with nonvarus alignment it was 0.02° of valgus (range, 3.6° varus to 4.6° valgus). Graft survivorship was 95.3% in the varus group and 95.8% in the nonvarus group (P = .918) at 5 years postoperatively. Reoperations after OCA transplantation occurred in 14.0% of the varus group and 22.6% of the nonvarus group (P = .336). The mean International Knee Documentation Committee total score improved from 45.2 preoperatively to 74.8 at latest follow-up in the varus group and from 40.5 preoperatively to 72.3 at latest follow-up in the nonvarus group. Patient satisfaction was >85%.

Conclusion: Patients undergoing isolated OCA transplantation of the MFC had high rates (>90%) of graft survivorship and significant improvements in pain and function. Patients with mild preexisting varus malalignment were found to have no difference in the failure rate or clinical outcomes compared with patients with nonvarus alignment.

Keywords: knee; articular cartilage repair; osteochondral allograft transplantation; knee malalignment

Articular cartilage injuries of the knee are frequently seen in young patients, with some studies demonstrating a 36% prevalence in athletes[15] and a 66% prevalence in knee arthroscopic surgery.[3] The medial femoral condyle (MFC) is the most common site of injury at 43%, followed by the patella at 23%.[3] Symptoms in active patients can include persistent pain and recurrent swelling that limit participation in athletic endeavors. Cartilage injuries can progress to further degenerative osteoarthritis, with 50% of significant knee injuries developing arthritis at 10 to 20 years.[6,26] Given that articular cartilage has a limited innate healing capacity, a variety of cartilage restoration techniques have been developed to treat focal articular cartilage damage, including subchondral bone marrow stimulation, autologous chondrocyte implantation (ACI), osteochondral autograft transplantation, and fresh osteochondral allograft (OCA) transplantation. Current recommendations for the management of articular cartilage injuries consider the anatomic location of the defect as well as the size and depth of the articular cartilage lesion.[7,18,23,27]

Fresh OCA transplantation involves harvesting a size- and contour-matched segment of articular cartilage with

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its attached subchondral bone from a donor, and used within 28 days from procurement.[10,34] This osteochondral graft is then transferred to a corresponding defect in a patient using a press-fit dowel technique or a shell allograft with fixation. The advantages of OCA transplantation include its single-stage nature, predictable bone-to-bone healing, and ability to treat cartilage injuries of varying sizes and depths in either the primary or revision setting. Previous studies have reported OCA survivorship to be 80% at 10 years postoperatively,[16,24] with >75% return-to-sport rates.[11] OCA transplantation has predictable improvements in patient-reported outcomes, with 1 meta-analysis showing an aggregate improvement in the International Knee Documentation Committee (IKDC) score of 39.6,[14] which is greater than the minimal clinically important difference of 26.9.[33]

A variety of patient-specific characteristics have been found to be associated with worse outcomes and decreased survival after OCA transplantation. These include advanced patient age, elevated body mass index (BMI), degenerative cause of the lesion, previous surgical procedures, and advanced radiographic arthritis. In particular, coronal-plane malalignment has been proposed to negatively affect the outcomes of cartilage repair. Pathological varus or valgus alignment can result in elevated contact pressure in the affected compartment and subsequently place greater stress on the cartilage repair site.[5,17,20,22,32,36,37,40] Biomechanical studies have shown that 5° of varus malalignment increases peak contact pressure in the medial compartment 2-fold compared with neutral alignment.[2,21]

Coronal-plane malalignment of the knee can be addressed at the time of cartilage restoration with corrective osteotomy to restore alignment to evenly distribute contact pressure.[2,19,30] Some authors have reported improved survival rates and patient-reported outcomes after combined cartilage repair and high tibial osteotomy (HTO) for the treatment of MFC lesions.[4] However, others have found coronal-plane alignment to play a role in outcomes after ACI but not necessarily after OCA transplantation.[1] Concomitant HTO and OCA transplantation has been shown to have a >85% survivorship rate at 8 years[28] and a 79% return-to-sport rate.[25]

The purpose of this study was to evaluate how varus malalignment affects graft survivorship, reoperation rates, and patient-reported outcomes after isolated OCA transplantation of the MFC. We hypothesized that patients with varus alignment would have decreased graft survivorship, higher reoperation rates, and worse clinical outcomes after OCA transplantation compared with patients with nonvarus alignment.

METHODS

Patient Population

A retrospective review was performed on our institutional review board–approved registry of patients undergoing OCA transplantation of the knee (No. 13-6297). All patients signed an informed consent form to participate in the registry, and data were prospectively collected. The surgical indications for OCA transplantation were isolated International Cartilage Repair Society grade III or IV chondral or osteochondral lesions with persistent symptoms that were not alleviated with nonsurgical treatment. The primary diagnosis was determined at the time of surgery and included degenerative chondral lesions, traumatic chondral injuries, osteochondritis dissecans, fractures, and avascular necrosis. For the present study, we identified 76 patients (81 knees) who underwent isolated primary OCA transplantation of the MFC between 2005 and 2019 and for whom we had long-leg hip-to-ankle radiographs. Exclusion criteria were previous or concomitant osteotomy and patients treated with multifocal allografts. Of the 76 patients identified, 70 patients (74 knees) had a minimum 2-year follow-up and were included in the present analysis.

Definitions and Measurements of Coronal Alignment

Preoperative coronal alignment of the knee was evaluated utilizing standing hip-to-ankle radiographs. We utilized a combination of preoperative and first postoperative (1-month) radiographs (n = 51 and n = 23 knees, respectively) because of the limited availability of preoperative radiographs. The use of preoperative and 1-month postoperative radiographs was validated by performing a correlation analysis of a subset of patients who had radiographs at both time points, which showed a high correlation coefficient (0.92). Coronal alignment was used to categorize patients into 1 of 2 groups: varus or nonvarus. Varus was defined as when the weightbearing line (line from the center of the head to the center of the ankle) was medial to the medial tibial spine of the knee.[1] Nonvarus was likewise

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defined as when the mechanical axis of the limb was lateral to the medial tibial spine of the knee; this included patients with neutral and valgus alignment. The mechanical tibiofemoral angle was calculated from hip-to-ankle radiographs as the angle between the mechanical axis of the femur (femoral head to center of the condyles) and the mechanical axis of the tibia (center of the tibial plateau to center of the plafond). Mechanical axis deviation was calculated as the distance between the center of the knee and the weightbearing line.

Data Collection

Reoperations after OCA transplantation were recorded. OCA failure was defined as removal of the graft (revision OCA transplantation or conversion to arthroplasty). Patient-reported outcome measures (PROMs) were completed by patients preoperatively at the time of history and physical examinations and postoperatively at each regularly scheduled follow-up visit. Nonlocal patients were sent a follow-up questionnaire via mail. PROMs included the IKDC score, Knee injury and Osteoarthritis Outcome Score (KOOS), and modified Merle d'Aubigné–Postel score. Additionally, patient satisfaction was evaluated using a 5-point Likert-type scale, with responses of dissatisfied, somewhat dissatisfied, somewhat satisfied, satisfied, and extremely satisfied. Data from each patient's latest follow-up were used in the present analysis.

Surgical Procedure

Fresh OCA transplantation was performed by the senior author (W.D.B.) with a thin plug technique as previously described.[28] Preoperatively, the allograft donor and recipient were matched by measurements of the mediolateral proximal tibial width; on a standard anteroposterior radiograph, the tibial width of the recipient, corrected for magnification, was measured and matched with a direct caliper measurement of the tibial width for the donor. A size match was considered acceptable when the donor and recipient tibial width were within 2 mm. Fresh OCAs were obtained from donors aged 15 to 40 years who met the criteria of the American Association of Tissue Banks. All donor tissue was recovered within 24 hours of donor death and was processed and stored fresh at 4°C in tissue culture medium until the time of transplantation (up to 28 days). In brief, a medial parapatellar approach was used to expose the MFC. The size of the articular defect was measured, and the defect was drilled with an appropriately sized reamer to an overall depth of 5 to 8 mm. A corresponding cylindrical reamer was used on the donor graft to harvest a matching osteochondral bone plug. The donor bone plug was then gently inserted into the defect using a press-fit dowel technique to match the contour of the surrounding articular cartilage.

Statistical Analysis

Patient characteristics (age, height, weight, BMI, diagnosis, number of previous surgical procedures on operative knee) were compared using the chi-square test and independent-samples t test. The mean and median mechanical tibiofemoral angle and mechanical axis deviation were calculated for the varus and nonvarus groups. Kaplan-Meier survivorship was calculated for each group and compared using the log-rank test. Follow-up duration and PROM scores were compared between groups using the Mann-Whitney U test.

RESULTS

Of the 74 knees, 43 (58.1%) had varus alignment, and 31 (41.9%) had nonvarus alignment. Patients with varus alignment were 5.8 years older, on average, than patients with nonvarus alignment (P = .040), but no difference in height, weight, or BMI was found (Table 1). Patients with varus alignment were more likely to be male compared with patients with nonvarus alignment (P = .047). There were no differences in the underlying diagnosis between the groups (P = .723). The mean follow-up duration for all patients was 7.2 years, with a mean of 6.1 years in the varus group and 8.7 years in the nonvarus group.

The mean mechanical tibiofemoral angle for patients with varus alignment was 3.9° ± 1.7° of varus (range, 1.1° to 8.9°) (Figure 1). The mean mechanical tibiofemoral angle for patients with nonvarus alignment was 0.02° ± 1.7° of valgus (range, 3.6° varus to 4.6° valgus) (Figure 2). As we defined the varus and nonvarus groups based on the mechanical axis of the limb in relation to the medial tibial spine, some patients in the nonvarus group were calculated as having mild varus alignment. The mean mechanical axis deviation in the varus group was 14.4 mm (range, 3.8 to 36.3 mm) (Figure 3). The mean mechanical axis deviation in the nonvarus group was 0.83 mm of valgus (range, 6.1 mm medial to 17.1 mm lateral) (Figure 4).

The reoperation rate for the entire cohort was 17.6% (13/74) (Table 2). The reoperation rate in the varus group was 14.0% (6/43) compared with 22.6% (7/31) in the nonvarus group (Table 2), which was not statistically significant (P = .336). Overall, the OCA failure rate was 5.4% (4/74). Graft survivorship at 5 years was 95.3% in the varus group and 95.8% in the nonvarus group (P = .918) (Figure 5). The 2 patients who had OCA failure in the varus group had mechanical tibiofemoral angles of 3.2° and 3.8° of varus and underwent removal of the graft and conversion to unicompartmental knee arthroplasty at 1.8 and 1.5 years postoperatively, respectively. In the nonvarus group, 1 patient with a mechanical tibiofemoral angle of 0° underwent conversion to total knee arthroplasty at 7.5 years postoperatively. The other patient in the nonvarus group with a mechanical tibiofemoral angle of 1.1° of varus underwent femoral condyle resurfacing at 3.9 years postoperatively.

PROM scores (IKDC, KOOS, and modified Merle d'Aubigné–Postel) are shown in Table 3. Both the varus and nonvarus groups showed statistically significant improvements on PROMs after surgery. However, there were no statistically significant differences between groups in regard to the change in PROM scores from

TABLE 1
Patient Characteristics[a]

	Varus (n = 43 Knees)	Nonvarus (n = 31 Knees)	*P* Value[b]
Sex			.047
Female	10 (23.3)	14 (45.2)	
Male	33 (76.7)	17 (54.8)	
Age, y	33.5 ± 12.3	27.7 ± 10.7	.040
Body mass index	24.7 ± 3.1	23.7 ± 3.6	.208
Diagnosis			.723
Avascular necrosis	5 (11.6)	1 (3.2)	
Degenerative chondral lesion	8 (18.6)	5 (16.1)	
Fracture	1 (2.3)	0 (0.0)	
Osteoarthritis	1 (2.3)	1 (3.2)	
Osteochondritis dissecans	24 (55.8)	20 (64.5)	
Traumatic chondral injury	4 (9.3)	4 (12.9)	
Previous surgery	29 (67.4)	24 (77.4)	.348
No. of previous procedures	2.0 ± 1.2	2.1 ± 1.6	.819
No. of grafts			.628
1	26 (60.5)	17 (54.8)	
2	17 (39.5)	14 (45.2)	
Total graft area, cm^2	6.9 ± 2.8	6.4 ± 2.2	.463

[a]Data are presented as mean ± SD or n (%).
[b]Groups were compared using the chi-square or independent-samples *t* test.

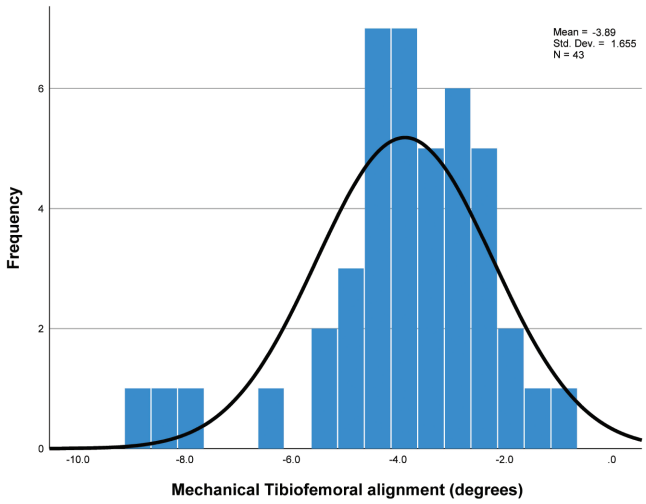

Figure 1. Mechanical tibiofemoral angle for patients with varus alignment.

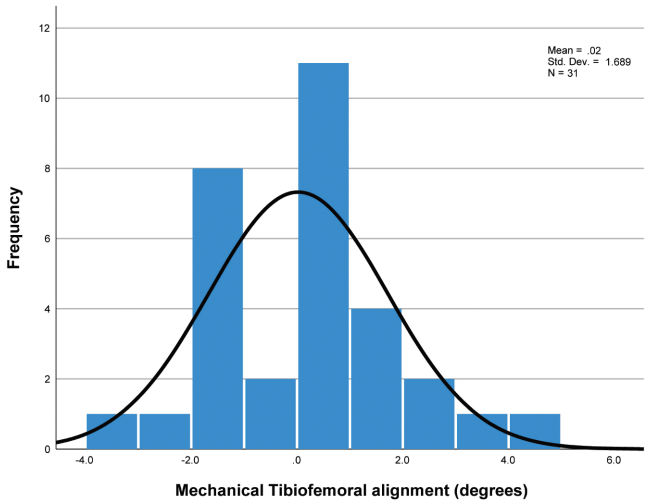

Figure 2. Mechanical tibiofemoral angle for patients with nonvarus alignment.

preoperatively to latest follow-up. In the varus and nonvarus groups, the mean IKDC total score improved by 28.5 and 31.8 points, respectively (P = .405). The KOOS Pain score improved by 17.2 and 17.0 points in the varus and nonvarus groups, respectively (P = .861). The modified Merle d'Aubigné–Postel score improved by 2.9 and 2.1 points in the varus and nonvarus groups, respectively (P = .272). The majority (90%) of patients reported that they were satisfied with the results of surgery after OCA transplantation (88.6% in varus group and 92.9% in nonvarus group; P = .684).

DISCUSSION

This study found that patients undergoing isolated OCA transplantation of the MFC had overall high rates of graft survival (>90%) at a mean of 7.1 years postoperatively with improvements in patient-reported outcomes similar to previously published cohorts.[9,35] Patients with mild varus malalignment (mechanical axis medial to the medial tibial spine; mean mechanical tibiofemoral angle, 3.9° of varus) were found to have similar graft survivorship and outcomes compared with patients with nonvarus alignment.[39] Overall, OCA transplantation for focal articular

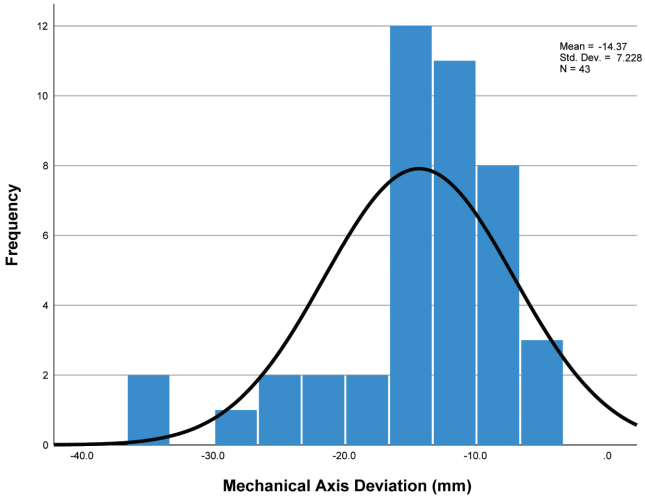

Figure 3. Mean mechanical axis deviation in the varus group.

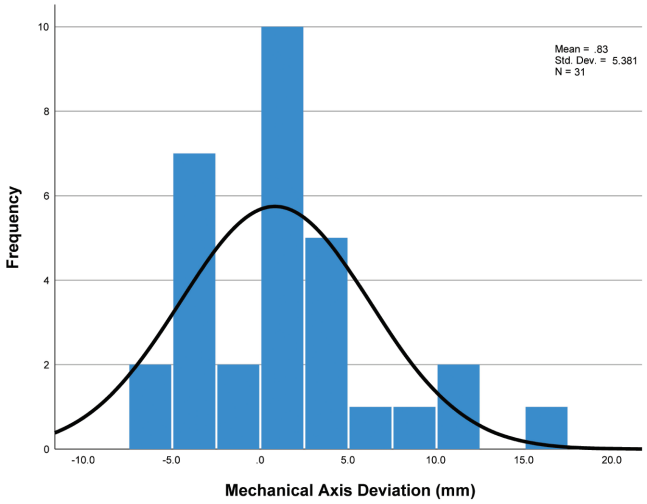

Figure 4. Mean mechanical axis deviation in the nonvarus group.

TABLE 2
Reoperations[a]

	Varus (n = 43 Knees)	Nonvarus (n = 31 Knees)	*P* Value
Further surgery	6 (14.0)	7 (22.6)	.336
Diagnostic arthroscopic surgery	4 (66.7)	1 (14.3)	
Debridement	1 (16.7)	2 (28.6)	
Loose body removal	1 (16.7)	3 (42.9)	
Osteotomy	0 (0.0)	1 (14.3)	
Meniscectomy	2 (33.3)	1 (14.3)	
Synovectomy	2 (33.3)	0 (0.0)	
Chondroplasty	1 (16.7)	0 (0.0)	
Scar tissue removal	0 (0.0)	1 (14.3)	
Unicompartmental knee arthroplasty	2 (33.3)	0 (0.0)	
Total knee arthroplasty	0 (0.0)	1 (14.3)	
Focal metal implant resurfacing	0 (0.0)	1 (14.3)	

[a]Data are presented as n (%). Some patients underwent >1 further surgical procedure.

cartilage defects of the MFC resulted in high patient satisfaction and predictable midterm survivorship. Reoperation rates were similar at 14.0% in the varus group and 22.6% in the nonvarus group, with no statistically significant difference. PROM scores improved, with postoperative IKDC and KOOS Quality of Life scores exceeding the minimal clinically important difference established by Ogura et al.[33] Patient satisfaction was 90%.

Coronal-plane malalignment of the knee has been proposed to be a cause for early failure of cartilage restoration procedures. However, only a few studies have examined the effect that malalignment has on patient outcomes after OCA transplantation. Ackermann et al[1] reported decreased survivorship after ACI in patients with varus or valgus malalignment, but they did not find an effect of malalignment on OCA survivorship. In our study, there were 2 OCA failures in each of the varus and nonvarus groups (total of 4 patients). Interestingly, these patients did not have an extreme varus or valgus deformity, as their mechanical tibiofemoral angle ranged from 3.8° of varus to 0° (neutral). In contrast, the patient in our cohort with the most significant deformity had a mechanical tibiofemoral angle of 8.9° of varus and graft survival at 3.9 years of follow-up.

Controversy exists in the literature regarding when to pursue a concomitant or staged coronal realignment procedure, with some authors recommending >3° of varus malalignment as a threshold and others advocating for a cutoff of ≥5°.[13,41] Biomechanical studies have shown that while peak contact pressure of the medial tibial plateau is 4 MPa in neutral alignment, this value increases to 8.1 MPa in patients with 5° of varus alignment.[21] In a varus knee, off-loading osteotomy decreases peak contact pressure in the medial compartment by nearly half,[2] which may allow for a more favorable biomechanical environment and better clinical outcomes with cartilage repair procedures.[7,40] Concomitant HTO with OCA transplantation has a survivorship rate of 85% at 8 years, and 79% of

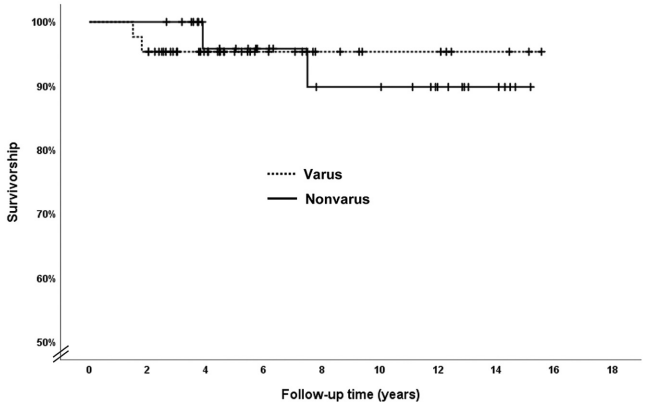

Figure 5. Graft survivorship at 5 years.

patients are able to return to sport.[25,28] However, osteotomy can have complication rates as high as 37%, including the loss of correction, fractures, delayed union, and symptomatic hardware.[29] In a series of patients undergoing OCA transplantation with concomitant osteotomy, the removal of hardware for symptomatic implants accounted for half of the reoperations performed.[12]

Several studies have explored outcomes after cartilage restoration with or without off-loading osteotomy. Meric et al[28] reported that patients undergoing OCA transplantation with concomitant HTO for a deformity >3° had a low failure rate (12%) at 9.3 years postoperatively. Minas et al[31] found greater long-term survival in patients undergoing combined HTO and ACI (88%) compared with those undergoing isolated ACI (66%). Using a national insurance database, Calcei et al[8] found that reoperation rates were higher in cases of isolated cartilage repair compared with cartilage repair with concomitant osteotomy (68.7% ACI vs 23.9% ACI + osteotomy; 34.8% OCA transplantation vs 16.3% OCA transplantation + osteotomy). Sochacki et al[38] found reduced reoperation rates when osteotomy was performed in conjunction with both ACI and OCA transplantation, although the rate was higher in patients undergoing ACI than OCA transplantation (67% vs 40%, respectively).[12] In comparison with other cartilage repair procedures, the benefits of OCA transplantation include immediate structural stability and graft incorporation via a rapid bone-healing paradigm. We postulate that these properties may allow the outcomes of OCA transplantation to be less sensitive to variations in coronal-plane alignment compared with other techniques.

Limitations of this study include the overall mild severity of pathological alignment in the varus group (mean mechanical tibiofemoral angle, 3.9° [range, 1.1° to 8.9°]), as our findings may not be attributable to patients with a greater deformity. Only 4 patients in our cohort had a severe varus deformity, with a mechanical tibiofemoral angle >5° of varus. Additionally, we utilized a combination of preoperative and first postoperative radiographs for analysis (n = 51 and n = 23 knees, respectively) because of the limited availability of preoperative radiographs as a result of the senior author's tertiary referral practice, with many patients referred from out of town. We attempted to account for this by comparing the mechanical tibiofemoral angle measured for patients who had both preoperative and 1-month postoperative radiographs and found a high correlation coefficient (0.92), thus validating this methodology. Graft failure rates were low (5%-7%) and thus may make comparisons of failure difficult. Lastly, this study was based on a single-surgeon cohort, and results may not be generalizable to all practices. Strengths of this study include the tightly controlled inclusion

TABLE 3
Patient-Reported Outcome Measure Scores[a]

	Varus	Nonvarus	*P* Value
IKDC			
Pain			
Preoperative	5.4 ± 2.7	5.7 ± 1.7	.822
Postoperative	3.1 ± 2.7	3.3 ± 2.8	.853
Change	–2.9 ± 3.2	–2.4 ± 3.2	.819
Function			
Preoperative	3.9 ± 1.7	3.1 ± 1.2	.916
Postoperative	7.1 ± 2.3	7.1 ± 2.6	.918
Change	4.0 ± 3.0	4.0 ± 2.6	.929
Total			
Preoperative	45.2 ± 17.6	40.5 ± 12.7	.347
Postoperative	74.8 ± 19.6	72.3 ± 24.2	.871
Change	28.5 ± 23.0	31.8 ± 20.6	.405
KOOS			
Symptoms			
Preoperative	65.4 ± 18.3	60.9 ± 17.7	.303
Postoperative	77.5 ± 21.6	78.9 ± 21.8	.515
Change	10.9 ± 28.0	17.9 ± 24.3	.393
Pain			
Preoperative	67.2 ± 18.2	68.5 ± 16.6	.898
Postoperative	84.4 ± 19.3	85.2 ± 18.2	.659
Change	17.2 ± 28.2	17.0 ± 19.4	.861
Activities of Daily Living			
Preoperative	77.3 ± 17.5	76.9 ± 16.7	.872
Postoperative	90.0 ± 19.2	91.4 ± 14.9	.742
Change	12.3 ± 27.0	16.1 ± 16.3	.992
Sports and Recreation			
Preoperative	41.0 ± 28.6	35.4 ± 24.4	.524
Postoperative	70.4 ± 27.1	65.6 ± 27.3	.506
Change	29.2 ± 42.1	31.4 ± 35.7	.841
Quality of Life			
Preoperative	24.9 ± 20.4	26.3 ± 16.6	.600
Postoperative	61.7 ± 28.6	64.9 ± 27.9	.814
Change	36.5 ± 31.6	40.3 ± 26.2	.574
Modified Merle d'Aubigné–Postel score			
Preoperative	13.5 ± 2.1	13.8 ± 1.3	.630
Postoperative	16.4 ± 2.1	15.9 ± 2.3	.357
Change	2.9 ± 2.4	2.1 ± 2.2	.272

[a]Data are presented as mean ± SD. IDKC, International Knee Documentation Committee; KOOS, Knee injury and Osteoarthritis Outcome Score.

criteria of patients undergoing isolated OCA transplantation of the MFC only (without those undergoing multifocal treatment or significant concomitant procedures) as well as the high follow-up rate of prospectively collected data.

CONCLUSION

Patients with mild varus malalignment (mechanical axis medial to the medial tibial spine; mean mechanical tibiofemoral angle, 3.9° of varus) undergoing fresh OCA transplantation of the MFC were found to have similar high graft survivorship, patient-reported outcomes, and satisfaction scores compared with patients with nonvarus alignment. Improved outcomes were preserved at a mean of 7.2 years of follow-up. In this scenario, concomitant valgus-producing or neutralizing osteotomy may not provide additional clinical benefits over OCA transplantation alone.

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