Outcomes of Bulk Fresh Osteochondral Allografts for Cartilage Restoration in the Knee

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Background: Symptomatic osteochondral defects of the knee in young patients can cause substantial disability and predispose to osteoarthritis. Fresh osteochondral allografts (FOCAs) are a treatment option for such defects. With our institution having one of the longest-running FOCA programs, we investigated the long-term outcomes of bulk FOCA in the knee, focusing on graft survivorship, function, complications, and reoperation.

Methods: A total of 244 patients underwent bulk FOCA in the knee from 1972 to 2018, with a mean age of 37.8 years (range, 10 to 75 years) and a mean follow-up of 9.0 years (range, 1.0 to 29.8 years). Cartilage defects were very large and uncontained, such that they were not amenable to plug transplantation. Survivorship according to Kaplan-Meier analysis was the primary outcome, and failure was defined as conversion to total knee arthroplasty, repeat allograft, graft removal, knee arthrodesis, or amputation. Functional outcome was evaluated with use of the modified Hospital for Special Surgery (mHSS) score, and radiographic evidence of osteoarthritis was classified with use of the Kellgren-Lawrence grading scale.

Results: Graft survivorship was 86.6% at 5 years, 73.3% at 10 years, 58.1% at 15 years, 43.7% at 20 years, 31.9% at 25 years, and 22.6% at 30 years. The most common complications were pain (14.8%), malalignment (13.9%), and stiffness (5.8%). A total of 93 grafts (38.1%) failed at a mean of 11.0 years (range, 0.5 to 34.0 years). The mean mHSS score improved significantly, from 68.7 (range, 19 to 91) preoperatively to 80.3 (range, 52 to 100) at the time of the latest follow-up ($p < 0.001$). Preoperative mHSS score had a negative correlation with Kellgren-Lawrence grade at the time of the latest follow-up. Multivariate analysis revealed that graft location (i.e., medial-sided or multiple grafts) and increased age were significantly negatively associated with survival. Ten-year survival was >80% in patients below 50 years old, but <40% in patients >60 years old.

Conclusions: Bulk FOCA provided promising long-term graft survival and functional improvement in patients <50 years old. It can delay or prevent the need for total knee arthroplasty in young patients. Older patients and patients with a medial-sided graft, or multiple grafts within the same knee, had a less favorable prognosis.

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

Symptomatic osteochondral defects of the knee in young patients, commonly caused by traumatic injury, result in substantial disability and predispose to osteoarthritis[1,2]. Articular cartilage defects >3 cm in diameter rarely heal, especially when a lesion of the subchondral bone is involved[3,4]. In elderly patients, total knee arthroplasty (TKA) is an appropriate treatment. Although TKA offers reliable outcomes, biological alternatives are preferred in younger patients because of their increased lifespan and activity levels, which cause concern for polyethylene wear, osteolysis, early aseptic failure, and subsequent revision procedures[5,6]. In a previous study, only 40% of patients <40 years old had a good or excellent functional score following TKA, and the rate of aseptic failure was 12.5% at 8 years[7]. Higher rates of

Disclosure: The **Disclosure of Potential Conflicts of Interest** forms are provided with the online version of the article (http://links.lww.com/JBJS/G694).

Fig. 1-A

Fig. 1-B

Fig. 1-C

Figs. 1-A, 1-B, and 1-C Preoperative (**Fig. 1-A**), postoperative (**Fig. 1-B**), and latest available (mean, 8.9 years postoperatively). (**Fig. 1-C**) anteroposterior radiographs of a posttraumatic lateral tibial plateau osteochondral defect in a 43-year-old woman who underwent bulk FOCA and high tibial osteotomy.

Fig. 2-A

Fig. 2-B

Fig. 2-C

Figs. 2-A, 2-B, and 2-C Preoperative (**Fig. 2-A**), postoperative (**Fig. 2-B**), and latest available (mean, 5.3 years postoperatively). (**Fig. 2-C**) anteroposterior radiographs of a posttraumatic medial femoral condyle and medial tibial plateau osteochondral defect in a 25-year-old man who underwent bulk FOCA and high tibial osteotomy.

TABLE I mHSS Scoring System for Patient Outcomes*

Pain intensity: How severe is your pain?	
None	35
Mild	28
Moderate	21
Severe	14
Rest pain	0
Instability: Does your knee feel unstable or give out?	
No	10
Occasionally	7
Moderately	4
Severe (use brace)	0
Walking aids: Do you use any walking aids?	
None	5
Cane	3
Crutches	1
Walker	0
Walking distance: On a flat surface (like in a mall) how far can you walk?	
>1 mile	10
>1 to 5 blocks	6
1 block	3
Inside house	1
Confined to bed	0
Extension block: Can you straighten your knee as much as the normal side?	
No deformity	10
<5°	7
5° to 10°	4
10° to 20°	2
>20°	0
Flexion: How much can you bend your knee?	
>120°	20
90° to 120°	15
45° to 90°	8
<45°	0
Effusion: Is the knee swollen at this time?	
No	10
Moderately	5
Severely	0

*Reproduced from[21]: McDermott AG, Langer F, Pritzker KP, Gross AE. Fresh small-fragment osteochondral allografts. Long-term follow-up study on first 100 cases. Clin Orthop Relat Res. 1985 Jul-Aug;(197):96-102.

aseptic and septic loosening and higher rates of revision following TKA in younger patients have been reported in literature[7,8].

Fresh osteochondral allograft (FOCA) transplantation has emerged as an attractive option to treat osteochondral defects over the past several decades. Although contained lesions may be treated with a trephined plug graft, very large and uncontained defects >3 cm in diameter and >1 cm in depth can be treated with a large, screw-fixated "bulk" FOCA[9-12]. This treatment has shown successful short to mid-term outcomes, with survival ranging from 64% to 74.8% at 15 years[9-12]. Although cartilage transplantation is costly and requires an organized transplant program[13], transplanted chondrocytes can survive ≥25 years without tissue matching or immunosuppressive therapy[14-16]. Bulk FOCA procedures pose a minor risk of infection, malalignment, stiffness, and persistent arthritic changes, and are at higher risk for graft failure and fragmentation compared with smaller allografts[17-19]. When indicated, concomitant meniscal transplantation and realignment osteotomy show improved durability and functional outcomes[11].

Literature is limited regarding the long-term outcomes of bulk FOCA transplantation[9-12,19]. With our institution having one of the longest-running FOCA programs, we investigated the long-term outcomes of bulk FOCA in the knee, with a focus on survivorship, complications, reoperations, and functional and radiographic outcomes.

Materials and Methods

With approval from the institutional research ethics board (Mount Sinai Hospital REB; Project ID 17-0099-C), we performed a retrospective review of our FOCA database from the time it was created in 1972 to 2018. We included data for 275 patients who underwent bulk FOCA transplantation of the knee. We decided to require a minimum follow-up of 1 year on the basis of healing time and the assumption that any patient with a short-term complication would have presented to us within that time frame, as we were the major center for FOCA procedures in Canada. A total of 31 patients were excluded for not meeting the minimum follow-up. Failed procedures that required conversation to TKA or a repeat FOCA transplantation were included even if follow-up was <1 year. Thus, the final cohort included 244 patients who underwent FOCA transplantation performed by 1 of 3 surgeons with extensive experience with the procedure (A.E.G., O.A.S., and P.R.T.K.).

Surgical Technique

Procedures were performed according to the American Association of Tissue Banks criteria[20]. Donor-to-recipient size matching was performed with use of standardized knee radiographs prior to harvesting the graft. Grafts were harvested within 24 hours of the death of the donor, with the capsule and synovial membrane intact, and were stored at 4°C in a sterile container with 1 g of cefazolin and 50,000 units of bacitracin. Transplantation was performed between 72 hours and 14 days after harvesting.

The recipient knee was approached through a midline incision followed by a parapatellar arthrotomy. The osteochondral defect was excised in a central-to-peripheral

TABLE II Available Sample Size from Final Cohort at Various Time Points*

	Baseline	Follow-up <1 Year	Follow-up 1 to <5 Years	Follow-up 5 to <10 Years	Follow-up 10 to <30 Years
Demographic data (Table II)	244				
Graft and procedure characteristics (Table III)	244				
Complications	244	3	86	60	95
Reoperations		3	86	60	95
Graft survival		3	86	60	95
Paired functional scores	102	2	38	27	35
KL grade	52	0	28	14	42

*A total of 241 patients with minimum 1-year follow-up and 3 patients who experienced failed treatment prior to 1 year were included in the final cohort of 244 patients.

manner until bleeding bone was reached. Defect measurements were taken, and a bulk FOCA was matched in shape and size. The corresponding graft from the donor was placed into the recipient and secured with partially threaded metal cancellous screws (Figs. 1-A through 2-C). In cases with a severely damaged meniscus, meniscal transplantation was undertaken. Preoperatively, if standing radiographs indicated that the weight-bearing axis would pass through the compartment with the allograft, a realignment osteotomy, such as a valgus-producing high tibial osteotomy or varus-producing distal femoral varus osteotomy, was performed to offload the graft.

Postoperatively, patients who underwent an osteotomy had the knee placed in a cast for 2 weeks, followed by a hinged brace with unrestricted movement for a further 6 weeks. All patients remained non-weight-bearing for 3 months to allow graft healing. When there was clinical and radiographic evidence of graft incorporation, patients were allowed to resume regular activity.

Outcome Measures

Demographic, graft-related, and surgical data were collected by chart review (performed by A.D.).

The primary outcome was survivorship, with the end point defined as reoperation with graft removal (e.g., conversion to TKA or a repeat FOCA). Secondary outcomes were functional as measured with use of the modified Hospital for Special Surgery (mHSS) knee score[21] (Table I) and degenerative knee changes as measured with use of the Kellgren-Lawrence (KL) grade. Imaging consisted of weight-bearing anteroposterior, lateral, and skyline knee views (scored by A.D.). For patients who experienced failed FOCA, mHSS and KL grades immediately prior to reoperation were utilized as the most recent scores in the analysis. Complications including nonunion, infection, graft osteoarthritis, persistent malalignment, stiffness, and others were recorded.

Statistical Analysis

Allograft survivorship was evaluated with use of Kaplan-Meier analysis with 95% confidence intervals (CIs). Failure was defined as conversion to TKA, repeat allograft, graft removal, knee fusion, or amputation. Cox regression analysis was utilized to assess the effect of age, sex, preoperative diagnosis, graft location, preoperative alignment deformity,

TABLE III Patient Characteristics*

Age *(yr)*	37.8 (10 to 75)
Male sex	144 (59.0%)
No. of past surgeries on involved knee	1.44 (0 to 9)
Time since injury† *(wk)*	50.0 (1 to 492)
Left-sided defect	122 (50.0%)
Surviving grafts	151 (61.9%)
Follow-up for surviving grafts *(yr)*	9.0 (1 to 29.8)
1 to <5 years	60 (24.6%)
5 to <10 years	40 (16.4%)
10 to <30 years	51 (20.9%)
Survival for failed grafts *(yr)*	11.0 (0.5 to 34)
Pre-procedural alignment deformity	185 (75.8%)
Valgus	122 (50.0%)
Varus	63 (25.8%)
Primary diagnosis	
Trauma	188 (77.1%)
Osteochondritis dissecans	44 (18%)
Avascular or spontaneous necrosis	8 (3.3%)
Dysplasia or tumor	4 (1.6%)

*Values are given as the mean with the range in parentheses or as the count with the percentage in parentheses. †Data available for 223 patients.

TABLE IV Graft and Procedure Characteristics*

FOCA technique – bulk allograft fixation	244 (100.0%)
FOCA location	
Femoral condyle, lateral	45 (18.4%)
Femoral condyle, medial	39 (16.0%)
Tibial plateau, lateral	110 (45.1%)
Tibial plateau, medial	21 (8.6%)
Bipolar, lateral	8 (3.3%)
Bipolar, medial	15 (6.2%)
Bipolar, other (i.e., intercondylar, patellar, multiple)	6 (2.5%)
Received osteotomy†	163 (66.8%)
High tibial osteotomy	75 (30.7%)
Distal femoral varus osteotomy	88 (36.1%)
Received meniscal allograft	126 (51.6%)
No. of screws for graft fixation	2.2 (0-5)

*Values are given as the count with the percentage in parentheses or as the mean with the range in parentheses. †Of 185 patients with pre-procedural alignment deformity, 163 had a deformity that was expected to load the graft and therefore received osteotomy.

and osteotomy. Preoperative and latest follow-up mHSS scores were compared with use of paired t tests. The correlation between the KL grade at the latest follow-up and mHSS score was assessed with use of Spearman rank correlation analyses. The Mantel-Cox log-rank test was utilized to conduct a subgroup analysis of survival on the basis of graft location and primary diagnosis. Significance was set at 0.05. Statistical analyses were performed with use of SPSS (version 25; IBM).

Source of Funding
No external funding or benefits were received for this study.

Results

Demographic, procedural, complication, reoperation, and survival data were available for 244 patients (Tables II through VI). Paired preoperative and latest follow-up mHSS scores and latest follow-up radiographs made at a minimum of 5 years were available for 102 and 56 patients, respectively (Table VII). The mean age of patients at the time of the index procedure was 37.8 years (range, 10 to 75 years). The primary diagnosis was trauma in 77.1% of patients, followed by osteochondritis dissecans in 18.0%, necrosis in 3.3%, and tumor in 1.6%. In traumatic cases, the index surgical procedure was performed approximately 50 weeks (range, 1 to 492 weeks) after the initial injury. The mean follow-up was 9.0 years (range, 1.0 to 29.8 years) for the surviving grafts. A total of 93 grafts reached an end point at a mean of 11.0 years (range, 0.5 to 34 years). Of 185 patients with preoperative alignment deformities, 163 were expected to load the graft and so underwent concomitant realignment osteotomy. In total, 75 patients (30.7%) underwent valgus-producing high tibial osteotomy. The most common graft locations were the lateral tibial plateau in 110 patients (45.1%) (Figs. 1-A, 1-B, and 1-C), lateral femoral condyle in 45 patients (18.4%), medial femoral condyle in 39 patients (16.0%) (Figs. 2-A, 2-B, and 2-C), and medial tibial plateau in 21 patients (8.6%) (Table IV).

Survivorship

Kaplan-Meier survival was 86.6% (95% CI, 82.1% to 91.1%) at 5 years, 73.3% (95% CI, 66.6% to 80.0%) at 10 years, 58.1% (95% CI, 49.7% to 66.5%) at 15 years, 43.7% (95% CI, 34.5% to 52.9%) at 20 years, 31.9% (95% CI, 21.7% to 42.1%) at 25 years, and 22.6% (95% CI, 11.0% to 34.2%) at 30 years (Fig. 3).

The mean survivorship of all 244 patients, up to failure or latest follow-up, was 9.7 years. Of the 93 patients (38.1%) who underwent reoperation with graft removal (which was considered failure of treatment), 41 experienced graft collapse and 3 had nonunion. The remaining 50 patients underwent conversion to TKA for osteoarthritis.

A univariate Cox regression analysis found that increased age (hazard ratio [HR], 1.04; 95% CI, 1.03 to 1.06; $p < 0.001$) and graft location (HR, 1.13; 95% CI, 1.02 to 1.26; $p = 0.022$) were significant factors influencing survival. Ten-year survival was >80% in patients <50 years old compared with <40% in patients >60 years old (Fig. 4). Lateral grafts of the femoral condyle or tibial plateau tended to have longer survival compared with medial

TABLE V Postoperative Complications*

Persistent pain	36 (14.8%)
Persistent malalignment	34 (13.9%)
Stiffness or effusion	14 (5.8%)
Graft osteoarthritis	13 (5.3%)
Graft fracture	5 (2.0%)
Infection	5 (2.0%)
Instability	5 (2.0%)
Loose bodies	4 (1.6%)
Nonunion	3 (1.2%)
Partial resorption	2 (0.8%)
Hardware-related pain	1 (0.4%)
Chondromalacia patellae	1 (0.4%)
Subluxation	1 (0.4%)
Deep vein thrombosis	1 (0.4%)

*Values are given as the count with the percentage in parentheses. Twelve patients reported >1 complication.

TABLE VI Survival and Reoperations*

Reoperation with graft retention	70 (28.7%)
New or revision osteotomy	30 (12.3%)
Hardware removal	29 (11.9%)
Arthroscopic debridement	23 (9.4%)
Meniscectomy	2 (0.8%)
Soft-tissue release	1 (0.4%)
Anterior cruciate ligament reconstruction	1 (0.4%)
Biopsy	1 (0.4%)
Reoperation with graft removal	93 (38.1%)
Total knee arthroplasty	75 (30.7%)
Repeat FOCA	8 (3.3%)
Debridement with graft removal	5 (2.1%)
Knee fusion	3 (1.3%)
Amputation	2 (0.8%)

*Values are given as the count with the percentage in parentheses. Forty-eight patients underwent >1 reoperation.

grafts. Multiple grafts within the same knee also had a less favorable prognosis. Subgroup analysis with use of the log-rank test confirmed survival differences based on graft location ($p < 0.001$). In regression analysis, concomitant osteotomy ($p = 0.44$), sex ($p = 0.09$), preoperative alignment deformity ($p = 0.11$), and primary diagnosis ($p = 0.44$) did not significantly influence survival. Subgroup analysis with use of the log-rank test confirmed no significant differences in survival based on primary diagnosis ($p = 0.12$).

Complications and Reoperations

Eighty patients (32.8%) developed at least 1 postoperative complication (Table V). Persistent pain was reported in 36 patients, persistent malalignment was reported in 34 patients, stiffness or effusion was reported in 14 patients, and graft osteoarthritis was reported in 13 patients. Twelve patients (4.9%) developed >1 complication. Overall, 132 patients (54.1%) had further operations, of whom 48 had >1 (Table VI). Of 70 patients (28.7%) who had reoperations with graft retention, 30 were new or revision osteotomies, 29 were hardware removals, and 23 were debridement procedures. A total of 93 grafts (38.1%) failed at a mean of 11.0 years (range, 0.5 to 34.0 years).

Functional Outcome

The mean mHSS score improved from 68.7 (range, 19 to 91) preoperatively to 80.3 (range, 32 to 100) at the time of the latest follow-up ($n = 102$; $p < 0.001$), a difference that stayed

TABLE VII Paired Preoperative and Postoperative mHSS Scores*

	Preoperative	Postoperative	P Value
Excellent (85 to 100)	10 (4.1%)	52 (21.3%)	
Good (75 to 84)	23 (9.4%)	18 (7.4%)	
Fair (60 to 74)	49 (20.1%)	22 (9.0%)	
Poor (<60)	20 (8.2%)	10 (4.1%)	
mHSS for surviving FOCAs			
1 to <5 years	66.6 ± 15.7 (25)	80.1 ± 12.1 (25)	<0.001†
5 to <10 years	72.3 ± 12.2 (12)	81.3 ± 15.8 (12)	0.031†
10 to <30 years	69.9 ± 12.9 (23)	89.4 ± 7.1 (23)	<0.001†
Overall for surviving FOCAs	69.0 ± 14.0 (60)	83.7 ± 12.8 (60)	<0.001†
mHSS for failed FOCAs			
1 to <5 years	66.5 ± 13.7 (15)	76.1 ± 16.3 (15)	0.063
5 to <10 years	69.5 ± 9.9 (15)	75.0 ± 16.9 (15)	0.053
10 to <30 years	69.2 ± 11.8 (12)	74.2 ± 14.2 (12)	0.206
Overall for failed FOCAs	68.4 ± 11.7 (42)	75.1 ± 15.6 (42)	0.011†
mHSS for all FOCAs			
1 to <5 years	66.6 ± 14.8 (40)	78.6 ± 13.8 (40)	<0.001†
5 to <10 years	70.7 ± 10.9 (27)	77.8 ± 16.4 (27)	<0.006†
10 to <30 years	69.6 ± 12.4 (35)	84.2 ± 13.4 (35)	<0.001†
Overall FOCAs	68.7 ± 13.0 (102)	80.3 ± 14.2 (102)	<0.001†

*Values are given as the count with the percentage in parentheses or as the mean ± standard deviation with the count in parentheses. Total included patients with paired mHSS scores = 102. †Significant.

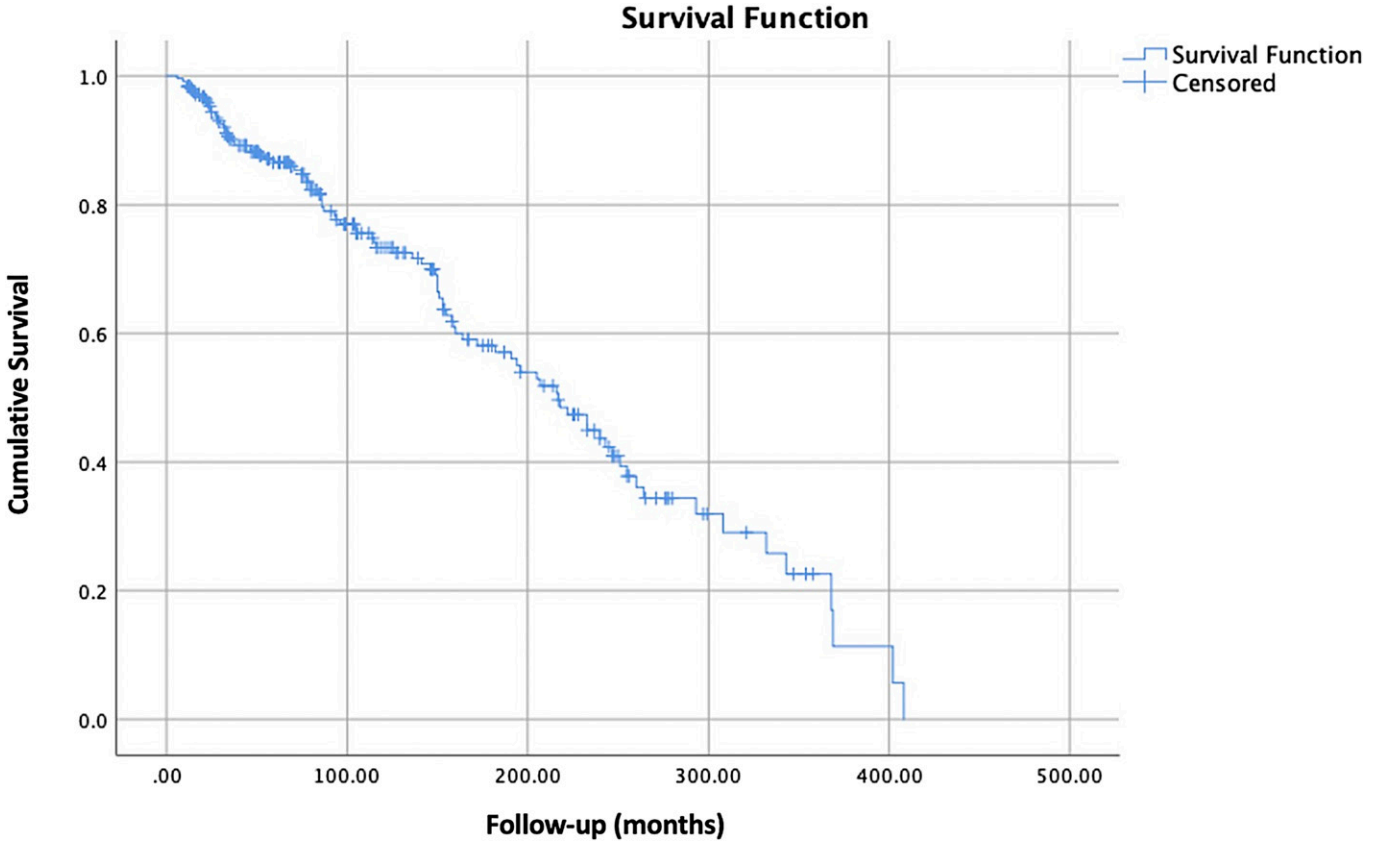

Fig. 3
Kaplan-Meier curve of overall graft survivorship.

consistent when patients were stratified into groups according to follow-up duration (Table VII). The mean mHSS score at the time of the latest follow-up for patients with a surviving FOCA was 83.7 compared with 75.1 for patients who experienced a failed FOCA. At the latest follow-up, the mean mHSS score was excellent (85 to 100) in 52 patients (21.3%), good (75 to 84) in 18 patients (7.4%), fair (60 to 74) in 22 patients (9.0%), and poor (<60) in 10 patients (4.1%). Spearman correlation demonstrated a significant negative correlation between preoperative mHSS score and KL grade at the time of the latest follow-up (Spearman rank coefficient, −0.643; $p = 0.01$).

Radiographic Outcomes

Radiographs from the latest follow-up were available for 84 patients (34.4%), of which 56 (23.0%) were made at a minimum of 5 years postoperatively (Table VIII). The mean follow-up was 16.2 years (range, 5 to 34). Of the 56 patients with a minimum 5-year follow-up, 7 (12.5%) had a KL grade of 0 to 1, 13 (23.2%) had a grade of 2, 22 (39.3%) had a grade of 3, and 14 (25.0%) had a grade of 4. Higher KL grades and more severe osteoarthritis were associated with longer follow-up times ($p = 0.03$).

Discussion

For osteochondral defects of the knee in relatively young and active patients, FOCA is an attractive treatment option because it may postpone or eliminate the need for TKA. Although smaller, contained lesions may be treated with newer techniques such as trephined plug grafts, the use of bulk FOCA to treat large chondral defects (i.e., >3 cm) in the knee has been documented in a number of studies[9-12,22-24]. A systematic review of knee FOCA studies found good durability and survival in 75.0% of 291 patients at a mean of 12.3 years postoperatively[19]. Defect locations included the femoral condyle (67.0%), tibial plateau (29.0%), and patellofemoral region (4.0%). In the present study, the most common graft location was the tibial plateau, likely because traumatic defects at this location may require bulk transplantation more often than femoral condylar lesions, for which trephined plug allografts are suitable.

The present findings are consistent with those of similar long-term FOCA studies. For the 244 included patients, the overall rate of failure was 38.1%, with grafts failing at a mean of 11.0 years. A survival of 43.7% at 20 years means that the need for TKA was delayed for 20 years in close to half of patients. These findings are encouraging considering that at the time of surgery, at a mean age of 37.8 years, many of our patients were not ideal candidates for TKA. When investigating graft survivorship by age group (Fig. 4), patients <50 years old generally had

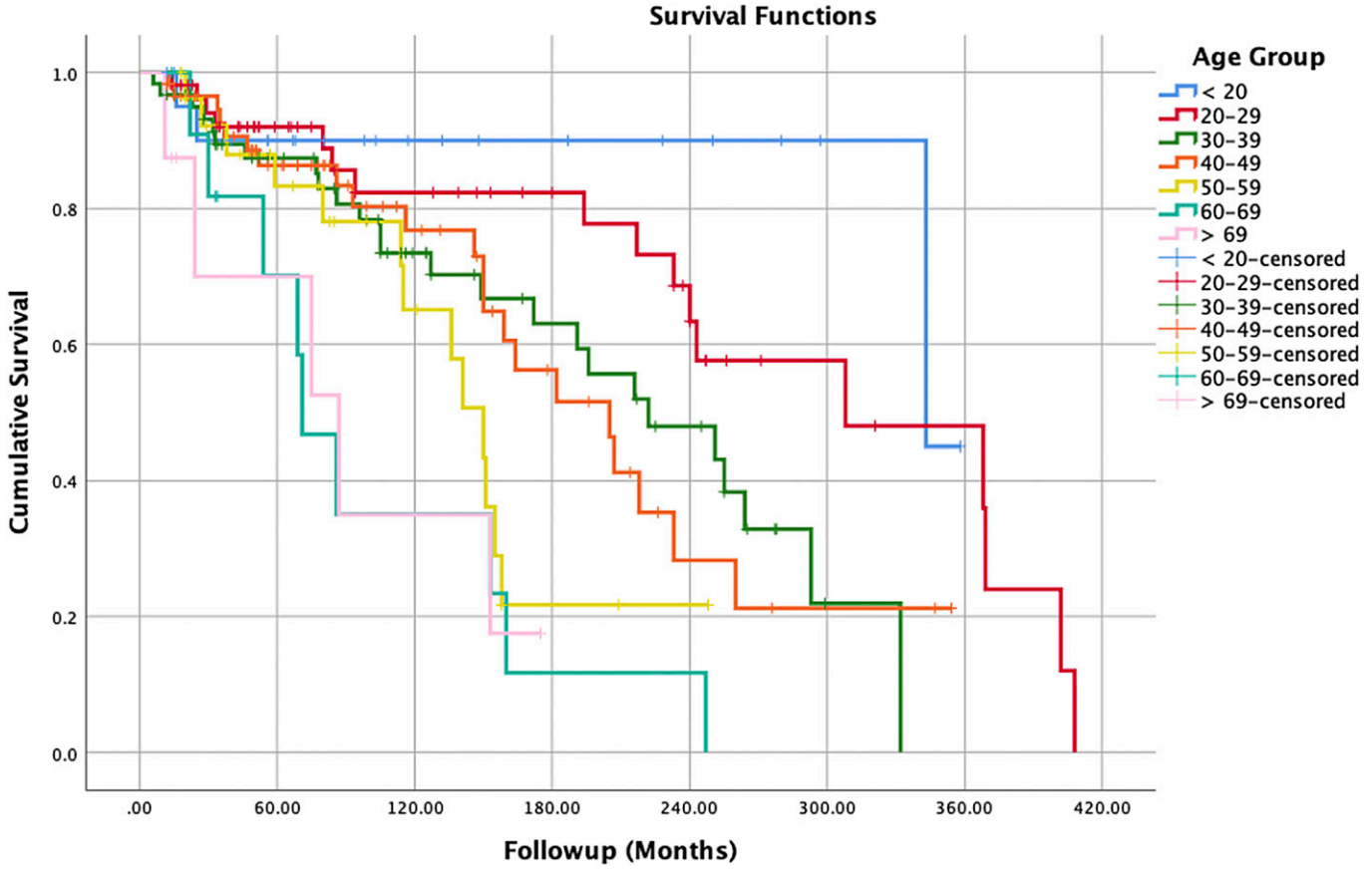

Fig. 4
Kaplan-Meier curves of graft survivorship by age group.

excellent survival until at least 10 years (>80.0%), with a gradual decline thereafter. Patients between the ages of 50 and 59 showed a rapid drop in graft survival at 10 years, highlighting the importance of careful patient selection in this age group. Patients who are healthy and active and have a strong preference for joint-preserving options may be appropriate candidates for FOCA in this age group. Poor graft survivorship in patients >60 years old suggests that bulk FOCA is not recommended for them. The finding in the present study that increased patient age was correlated with worse survivorship (HR, 1.04; 95% CI, 1.03 to 1.06; $p < 0.001$) suggests that arthroplasty may be a more suitable option for patients >60 years old. A randomized trial would help to further determine the value of bulk FOCA in light of more predictable outcomes with current arthroplasty practices. Prior studies have also suggested

TABLE VIII Radiographic Evidence of Osteoarthritis and Association with Clinical Outcome*

Osteoarthritis	No. of Patients	Follow-Up Duration *(yr)*	No. of Patients with mHSS Scores	mHSS Score
No/doubtful	7 (12.5%)	11.0 ± 4.9	4 (1.6%)	88.5 ± 3.7
Mild	13 (23.2%)	14.7 ± 6.9	3 (1.3%)	82.7 ± 15.8
Moderate	22 (39.3%)	15.8 ± 8.0	4 (1.6%)	86.5 ± 7.3
Severe	14 (25.0%)	20.8 ± 7.7	5 (2.0%)	79.6 ± 11.7
Total	56 (100%)	16.2 ± 7.8	16 (6.6%)	84.1 ± 9.9

*Values are given as the count with the percentage in parentheses or as the mean ± standard deviation. Fifty-six patients with radiographs taken at minimum of 5 years of follow-up were included, of whom 16 had mHSS scores available. The mean KL grade at the time of the latest follow-up was 2.8 (95% CI, 2.5 to 3.0). There was a significant difference between groups for follow-up duration ($p = 0.03$) but not for mHSS at latest follow-up ($p = 0.56$).

that increased age and increased preoperative symptom duration (>12 months) are risk factors for not returning to athletic activity[17,25].

The present analysis showed differences in survival based on graft location, with medial-sided grafts having poorer survival, which is consistent with a previous study by Abolghasemian et al.[10]. This finding is likely the result of the biomechanical load placed on the medial side of the knee. Previous clinical and histological studies determined that concomitant malalignment resulted in higher rates of graft failure as a result of delayed revascularization and additional loss of articular cartilage[11,16]. Realignment osteotomies such as distal femoral varus and high tibial osteotomy prevent excessive mechanical loading of allografts and have been demonstrated to contribute to long-term graft survival[9-11]. Pertaining to the outcomes of arthroplasty following osteotomy, recent systematic reviews have reported that when performed following high tibial osteotomy, TKA may be more technically challenging and may pose a significantly higher risk of revision in the long term (>10 years) compared with primary TKA (odds ratio, 2.09; 95% CI, 1.81 to 2.41; $p < 0.001$)[26-28]. Multiple grafts within the same knee, such as bipolar grafts, also had a less favorable prognosis relative to unipolar grafts. Meric et al. reported high rates of reoperation and failure in bipolar FOCA, with a 5-year survivorship of 64.1% in 48 knees[29]. A trend toward increased survivorship has been seen when clinically warranted meniscal transplants are performed in conjunction with FOCA[9,10].

Although greater than one-third of patients experienced minor postoperative complications, most of these complications could be expected following knee surgery and were not of great concern. For example, persistent pain, malalignment, and stiffness were reported most commonly (Table V). Despite this, postoperative mHSS functional scores, which account for pain, instability, and stiffness, were significantly improved. Similarly, although 70 minor reoperations were performed during which the graft was retained, almost all of these reoperations were osteotomies, hardware removals, or arthroscopic debridement (Table VI).

The present study had several limitations. As the first center in the world to perform FOCA transplantation, many patients (13.0%) were referred to us from all over the world. Given the retrospective nature of the study, data were not available for all outcomes for all patients. Although the data were extracted from our database, which was established in 1972, some potentially important items such as weight, body mass index, smoking status, and ligamentous reconstruction performed by an outside surgeon were not documented. Efforts were made to obtain relevant missing data from original patient charts, follow-up visits, and phone calls. We believed that the patients and data available at a mean follow-up of 9 years provided a sufficiently representative cohort. Second, we recognized that the mHSS is suited for arthroplasty patients, and other functional scores such as the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) might have been better for our population; however, because of the retrospective nature of our database, we did not have access to other scoring. Third, we excluded surviving grafts that had <1 year of follow-up but included cases that experienced failure <1 year postoperatively, which might have led to an underestimation of survivorship. Fourth, although realignment osteotomy was not found to significantly influence survival in our regression analysis, two-thirds of the population underwent realignment osteotomy, and it remains difficult to know whether the osteotomy alone improved the outcomes. Fifth, radiographic comparisons were limited because hard-copy radiographs were lost when our institution transitioned to digital radiographs in 2004.

Despite these limitations, this series of 244 patients with large, uncontained osteochondral defects of the knee treated with use of bulk FOCA is, to our knowledge, the largest in the literature. Bulk FOCA transplantation in the knee provides promising long-term graft survival and functional improvement in patients <50 years old. Anatomic location of the graft (i.e., medial-sided graft or multiple grafts within 1 knee) and increased age appeared to adversely affect graft survival. ■

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