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Long-Term Followup of the Use of Fresh Osteochondral Allografts for Posttraumatic Knee Defects

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Posttraumatic osteochondral defects of the distal femur or proximal tibia pose a reconstructive challenge for the young active patient. Fresh osteochondral allografts have been used to reconstruct these defects and this report deals with the long-term clinical and radiographic follow-up in this patient population. This is a prospective nonrandomized study. Sixty patients with an average followup of 10 years received femoral condylar grafts. Twelve grafts failed, requiring removing of the graft in three patients and conversion to total knee replacement in nine patients. Kaplan-Meier survivorship showed 95% graft survival at 5 years and 85% at 10 years. Sixty-five patients received fresh osteochondral allografts to reconstruct the tibial plateau with an average followup of 11.8 years. In this group of patients, conversion to total knee arthroplasty was done in 21 patients at a mean interval of 9.7 years. Survival analysis revealed 95% survival at 5 years, 80% at 10 years, and 65% at 15 years. Through our long-term prospective study, we confirm the value of fresh osteochondral allografts to reconstruct articular defects of the knee in the young active patient.

Level of Evidence: Therapeutic study, Level II-1 (prospective cohort study). See the Guidelines for Authors for a complete description of levels of evidence.

The presence of a full-thickness osteochondral defect in the knee of young or active individuals remains a problem in orthopaedic practice. Inevitable loosening of joint arthroplasty in such a young, active population has lead to the search for a biologic method of repair. Unloading osteotomy, debridement and microfracture techniques, mosaicplasty, periosteal grafts, and autologous chondrocyte transplantation are possible options for such patients, although each technique has limitations.[11,32,39,40,42] Realignment of the limb by osteotomy may not unload the involved area sufficiently and the patient then is left with a large osteochondral defect and ligament pseudolaxity.[25,33] Abrasion arthroplasty and microfracture techniques lead to the development at best of a hybrid of hyaline and fibrocartilage over the articular surface.[6,10,42,50] Mosaicplasty is limited to small osteochondral defects smaller than 3 cm in diameter and 1 cm in depth, and also requires the sacrifice of cartilage from another area of the joint.[7,24] Periosteal grafting of defects remains experimental in the clinical situation because there are no long-term studies with large numbers of patients.[42,43] Finally, autologous chondrocyte transplantation remains an expensive procedure that still is being investigated. It also does not directly address any associated major bone defects.[8,37,38]

The successful use of fresh osteochondral transplantation now has been documented for several decades.[22,23,31,34,44,53] Authors of early studies on allogenic cartilage transplantation showed this tissue to be immunologically privileged, showed fresh grafts to have hyaline cartilage, and showed that surviving chondrocytes were present several years after implantation.[14,15,28–30,35,41] Since 1972, the senior author and other colleagues have done this procedure successfully in patients with osteochondral defects larger than 3 cm in diameter and 1 cm in depth. A clinical followup study[23] as early as 1975 showed successful early outcomes, and in 1985, success was achieved in 75% of patients 5 years postoperatively.[34] More recently, authors found 95% survival at 5 years, 71% at 10 years, and 66% at 20 years.[19] It was learned that older patients, bipolar transplants, improper loading of the graft, and grafts for osteoarthritis-induced and steroid-induced avascular necrosis do not lead to good long-term outcomes.[19,34]

In the past, results of femoral condylar grafts and tibial plateau grafts have been reported together.[19] However,

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TABLE 1. Modified Hospital for Special Surgery Score for Patient Outcomes

Pain Intensity	Number of Patients	Instability	Number of Patients	Walking Aids	Number of Patients	Walking Distance	Number of Patients
None	35	None	10	None	5	<1 mile	10
Mild	28	Occasionally	7	Cane	3	One to five blocks	6
Moderate (occasional analgesics)	21	Moderate (with decreased activity)	4	Crutches	1	One block	3
Severe	14	Severe (uses brace)	0	Walker	0	Inside house	1
Rest pain	0					Confined to bed	0

more recently, the results of femoral condylar grafts have been reported separately from tibial plateau grafts,[2,49] and for the purpose of this paper we will report the results separately as well. The reason for this is the difference in the pathology and demographics of the two groups of patients. Also, other cartilage repair techniques are more commonly done on the femoral side than the tibial side, and therefore comparison between our indications and results on the femoral side can be compared with mosaicplasty and autologous chondrocyte transplantation. This is the first time that we have reported the long-term results on both the femoral and tibial sides as part of the same paper. We think this will give a better overview of our long-term results with this challenging reconstructive problem. The purpose of this paper is to examine the long-term clinical and radiological results as well as the survivorship of fresh osteochondral allografts for posttraumatic defects around the knee.

MATERIALS AND METHODS

In 1972, the first fresh osteochondral allograft was used for a posttraumatic tibial plateau defect of the knee. A prospective database was established in order to document the clinical and radiographic results as well as the survivorship of this operative procedure. This was not a randomized study because the patients had considerable osteochondral defects of the knee, and based on their ages and former levels of activity, they were not considered to be candidates for total knee replacement. Also, because of the size of the defect, they were not considered to be candidates for realignment osteotomy. Cases were recorded with clinical, radiographic and patient-derived subjective data. Eligible recipients were younger than 60 years and had traumatic unipolar osteochondral defects of at least 3 cm in diameter and 1 cm deep. Donors were younger than 30 years and were obtained through the Multiple Organ Retrieval and Exchange Programs (MORE). The harvested knee with its capsule intact was stored in Ringer's lactate with 1 g of cefazolin and 50,000 units of bacitracin for a maximum of 72 hours at 4°C. Donors were matched by size and morphology using standardized radiographs. Neither tissue typing nor blood matching was done. The American Association of Tissue Banks Guidelines were adhered to.[26]

The long-term clinical outcomes and survival analysis are presented for patients with a minimum of 5 years from the time of osteochondral allograft transplant surgery for posttraumatic unipolar defects. These patients are part of the same cohort as was previously published in 1997.[19]

A search was done on the computerized database for patients with unipolar posttraumatic osteochondral transplant to the knee between 1972 and 1995. These charts then were reviewed for demographic, diagnostic, and surgical details. A modified Hospital for Special Surgery (HSS) score (Table 1) routinely was used to record patient outcomes at each clinic visit.[34] Patients lacking outcome data within the past 12 months were contacted at their last known telephone number and a followup visit was arranged or a questionnaire was administered using the telephone. Referring physicians also were contacted to obtain recent 3-foot standing and routine radiographs of the knee.

The surgical team was composed of two groups: one group prepared the graft while the other prepared the recipient. Exposure of the recipient's knee is done through a midline skin incision followed by a parapatellar arthrotomy to expose the affected condyle or plateau. The damaged area is resected to bleeding bone while the donor fragment is trimmed to fit the defect created. The grafts are fixed with partially threaded 3.5-mm cancellous screws. The use of titanium screws is advised because of their increased MRI compatibility.

During surgery, the meniscus is evaluated. When the meniscus overlying the tibial plateau has been significantly damaged, it is resected and replaced with the attached allograft meniscus from the donor plateau. Already attached to its own bony anchors, the meniscus is repaired to capsule by nonabsorbable sutures. For the femoral condylar grafts, if the meniscus is damaged or absent, allograft meniscus is attached to capsule by several nonabsorbable sutures. Realignment of the involved leg is done to unload the graft where standing radiographs indicated that the weightbearing axis would pass through the compartment with the transplant. When measuring the biomechanical axis, any degrees of deformity toward the diseased compartment were an indication for osteotomy. Lateral–closing-wedge, high-tibial osteotomy is done for valgus realignment and a medial–closing-wedge, distal-femoral osteotomy is used to realign the limb into varus when necessary.[20,21] It is our policy to do the osteotomy during the same operation as the transplant is done. If the oste-

TABLE 1. Modified Hospital for Special Surgery Score for Patient Outcomes (*Continued*)

Extension Block	Number of Patients	Flexion	Number of Patients	Effusion	Number of Patients
No deformity	10	> 120°	20	None	10
< 5°	7	90–120°	15	Moderate	5
5–10°	4	45–90°	8	Severe	0
10–20°	2	< 45°	0		
< 20°	0				

otomy and the transplant involve the same side of the joint (ie, lateral femoral condyle and distal femoral varus osteotomy), the osteotomy is done at least 2 cm away from the interface between the graft and the host. A 2-week period of cylinder casting is followed by range of motion (ROM) exercises. A custom-molded ischial weightbearing orthosis is used for 1 year. To our knowledge, all patients were compliant with the wearing of this orthosis. Weightbearing is allowed in the brace after union of the osteotomy, usually at 8 weeks (Figs 1, 2).

Patients were assessed preoperatively and postoperatively using the modified HSS score, which tabulates data from clinical and patient-derived fields (Table 1). This knee rating system[34] has been used previously to determine knee function in our past reviews of fresh osteochondral grafting procedures. Patients were contacted and examined clinically and radiographically. In cases in which geographic constraints prohibited clinical examination in person, examination was completed by a local orthopedist, with questionnaires and radiographs being returned by mail.

Evidence of graft nonunion, fragmentation, collapse, resorption or the presence of degenerative changes was recorded. Joint degeneration was considered mild in which more than 50% of joint space was maintained and neither subchondral sclerosis nor osteophytes were present. Moderate changes involved collapse of greater than 75% joint space, mild subchondral sclerosis and 1 to 2 osteophytes. Severe degenerative changes involved complete loss of joint space, subchondral sclerosis, and multiple osteophytes.[2] Two independent orthopedic surgeons reviewed radiographs and where discordance existed, the greater degree of degenerative changes was recorded.

T tests and analysis of variance (ANOVA) were used to evaluate factors, which lead to poor clinical outcomes. Kaplan-Meier statistics were used to determine survivorship.[27] Survivorship was defined as graft removal, the need for arthroplasty, or HSS score of less than 70. Logistic regression was used to evaluate factors that potentially could predict poor graft survival such as patient age, gender, affected side of the transplant (medical versus lateral), meniscal transplant, and the need for osteotomy.

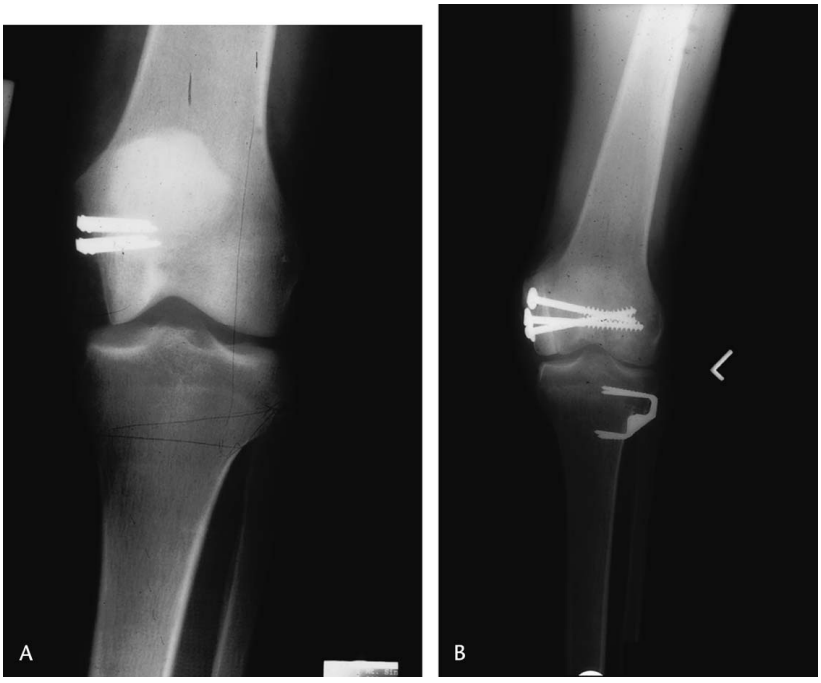

Fig 1A–B. (A) An AP xray of left knee of 35-year-old man with traumatic loss of medial femoral condyle is shown. (B) An AP xray of his left knee 8 years after reconstruction with fresh medial femoral condyle allograft and valgus closing-wedge proximal tibial osteotomy is shown.

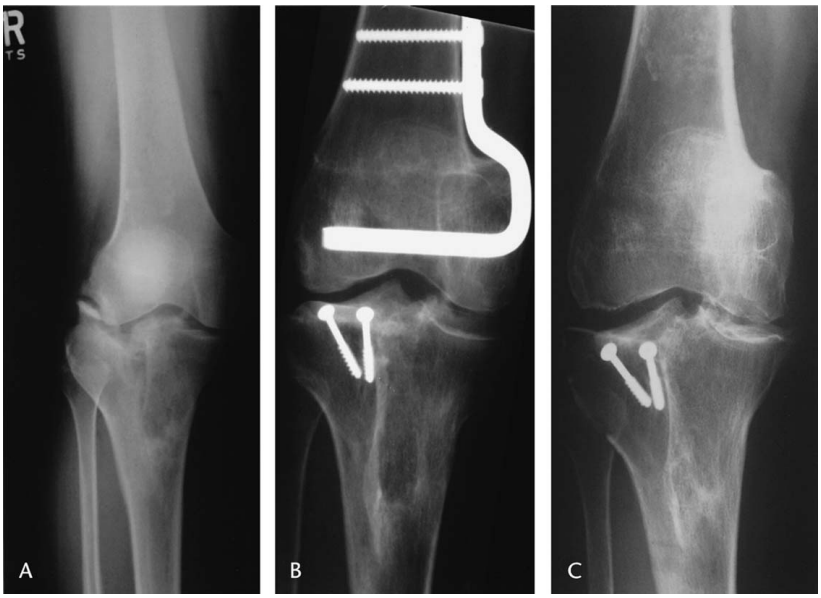

Fig 2A–C. (A) An AP xray of a 30-year-old woman with a fracture of the lateral tibial plateau of her right knee is shown 2 years after initial internal fixation. The hardware has been removed. (B) An AP xray 6 months after reconstruction with fresh lateral plateau allograft done in conjunction with distal femoral varus osteotomy is shown. (C) An AP xray 12 years after reconstruction shows the plateau graft and lateral compartment joint space are well maintained but the medial compartment shows degenerative changes.

RESULTS

Between 1972 and 1995, 72 osteochondral allograft transplants of the femur were done at the Mount Sinai Hospital in Toronto. Three patients died for reasons other than those associated with the transplant procedure. Of the remaining 69 patients with more than 5 years of followup, 60 (87%) were contacted and up-to-date scores were obtained. There were 48 (80%) men and 12 (20%) women, with an average age of 27 years (range, 15–47 years) at the time of surgery. The etiology of the osteochondral lesions was trauma in 36 patients (60%), osteochondritis in 17 patients (28%), osteonecrosis in six patients (10%), and osteoarthritis in one patient (2%). The left knee was transplanted in 29 patients (48%) and the right knee was transplanted in 31 (52%). The medial femoral condyle was involved in 30 patients (50%) and the lateral femoral condyle was involved in 30 (50%). In 10 (17%) cases, the patient's meniscus was damaged to such an extent that meniscal transplantation was done at the time of surgery. Realignment was done in 41 patients (68%), with a high-tibial osteotomy done in 25 patients (61%) and a distal-femoral varus osteotomy done in 16 (39%). The average followup was 120 months (range, 58–259 months).

In this series of patients that received distal femoral osteochondral allografts, the clinical results and survivorship studies were considered to be very encouraging at an average of 10 years followup. Of the 60 patients in this study, 12 had failed grafts (20%). Of these 12 patients, three patients had graft removal alone and nine patients had graft removal accompanied by total knee arthroplasty (Table 2). One case of deep infection (Patient 19) resulted in early failure with graft removal at 6 months. This represents the only case of deep infection in the current study. Three grafts failed at fewer than 5 years and one graft failed at 6 years as the result of graft fragmentation and collapse. The remaining nine grafts failed at greater than 5 years as the result of late osteoarthritic degeneration of the joint (Table 2). These nine grafts united to host bone with no fragmentation or resorption. There was complete loss of cartilage from the grafts. Joint incongruity was not identified as a causative factor in the 12 failed cases. Survival analysis using the Kaplan-Meier method revealed 95% survival at 5 years (95% confidence interval, 62%–100%),

TABLE 2. Failed Femoral Osteochondral Allograft Cases with Time to Failure, Cause of Failure, and Treatment of Failure

Patient Number	Time to Failure (months)	Cause of Failure	Corrective Procedure
2	36	Fragmentation	Graft removed
7	48	Fragmentation	TKA
11	157	Osteoarthritis	TKA
13	186	Osteoarthritis	TKA
16	69	Fragmentation	Graft removed
17	108	Osteoarthritis	TKA
18	61	Osteoarthritis	TKA
19	6	Deep Infection	Graft removed
31	240	Osteoarthritis	TKA
47	226	Osteoarthritis	TKA
51	36	Fragmentation	Regraft
55	178	Osteoarthritis	TKA

TKA = Total knee arthroplasty

85% survival at 10 years (95% confidence interval: 41%–100%), and 74% survival at 15 years (95% confidence interval: 16%–100%). Only 24 patients remained able to be analyzed at 10 years, and 12 patients at 15 years.

Of the 48 remaining patients, the mean modified HSS score was 83 of a possible 100 points. An excellent or good score was achieved in 29 patients (61%) and 11 patients (23%), respectively, whereas four (8%) patients had a fair score and four (8%) had a poor score.

No association was found between graft failure and the need for meniscal transplant, limb realignment, or positioning of the graft on the medial or lateral condyle. Also, in this study population the underlying etiology for the osteochondral defect did not have a bearing on the long-term outcome.

Radiographic evaluation revealed that the majority of patients still maintained an adequate joint space and had not gone on to severe arthritis. Of the 38 patients with adequate radiographs, 18 (48%) had no arthritis or mild arthritis, 10 (26%) had moderate arthritis, and 10 (26%) had severe arthritis. Radiographic evidence of arthritis on radiographs was associated with the long-term HSS scores. Patients with severe arthritis had lower HSS scores compared with patients with moderate ($p = 0.01$), mild ($p < 0.02$), or no arthritis ($p = 0.02$). Radiographic evidence of graft sclerosis and fragmentation was seen in nine patients (24%) whereas nonunion was observed in two patients (5%). Four of the nine patients with radiographic evidence of fragmentation required removal of the graft in fewer than 6 years. In the remaining patients, the graft appeared structurally intact and well united to the host bone.

For the tibial plateau grafts, followup was obtained for 65 of 67 patients (97%) with two patients being lost to followup after less than 1 year. One patient included in the study was lost to followup at 10.8 years after surgery and five patients died from unrelated causes after at least 5 years of followup. The average age of the 29 men and 36 women who were able to be followed up was 42.8 years (range, 26–69 years). Allograft reconstruction was done at an average interval of 4.0 years from trauma (range, 0.7–34 years). All patients had tibial plateau fractures, with most having previous open reduction and internal fixation.

TABLE 3. Previous Surgical Procedures Done on Patients before Fresh Osteochondral Grafting for Posttraumatic Plateau Defects

Operation	Number
Open reduction internal fixation	47
Menisectomy	3
Arthrotomy	4
Arthroscopy	15
Osteotomy	8

TABLE 4. Data on the Complications and Additional Surgical Procedures Done after Fresh Osteochondral Grafting for Plateau Defects in Sixty-Five Patients

Number	Complication
1	Deep venous thrombosis
1	Early loosening
4	Graft fracture
	Additional Surgery
1	Regrafting for early graft failure
4	Hardward removal from graft
5	Arthroscopy
10	Osteotomy
34	Other minor procedures (knee manipulation, removal of osteotomy fixation, etc)

The tibial defects were on the lateral side in 54 patients and on the medial side in 11 patients. Fifty-four of 65 patients (83%) had previous surgery on the same limb that was operated on in our study (Table 3), with the average number of procedures being 1.3 (range, 0–5 procedures). A list of postoperative complications and additional surgical procedures also is documented (Table 4). A meniscal allograft was used in 39 patients (60%), with 32 lateral and seven medial menisci being transplanted. Realignment osteotomy was done in 38 patients (58%). Distal femoral varus osteotomy was used in 26 patients and closing-wedge high-tibial osteotomy was used in 12 patients.

In the group of patients who had received tibial plateau osteochondral allografts, the clinical results and survivorship were similar to those patients who had received femoral condylar grafts. Sixty-five patients with an average age at osteochondral grafting of 42.8 ± 10.3 years (range, 26–69 years) were followed up for an average of 11.8 ± 5.0 years (range, 2–24 years). Followup of fewer than 5 years in several patients represented patients who had early conversion to total knee arthroplasty. A survivorship analysis (Kaplan-Meier life table) was used to predict the length of time that grafts remained intact and functioning. Study endpoints to define survivorship were (1) a patient's decision to proceed with knee arthroplasty, (2) the HSS score falling below 70 points or (3) revision surgery on the allograft for any reason. This analysis showed 95% survival at 5 years (95% confidence interval: 90%–100%); 80% survival at 10 years (95% confidence interval: 69%–90%); 65% survival at 15 years (95% confidence interval: 51%–79%), and 46% survival at 20 years (95% confidence interval: 28%–65%).

At the end of the study period, 44 of 65 grafts (68%) were in situ and functioning with an HSS score greater

than 70 points at an average of 12.9 ± 5.1 years. Conversion to knee arthroplasty occurred in 21 patients at a mean interval of 9.7 ± 4.4 years (range, 2–17 years) and two patients had HSS scores of fewer than 70 points. The mean HSS score for intact grafts at the end of the study period was 85.3 ± 11.0 points.

A meniscal allograft was used in 39 patients (60%). We were unable to identify differences in radiographic joint degeneration or HSS scores on the basis of meniscal transplantation in surviving grafts.

Radiographs were reviewed in 35 of 44 patients with intact grafts at the end of the study period (80%). There was radiographic union of the allograft to host bone in all cases. There was an 8.5% incidence of graft collapse in excess of 3 mm. Radiographs revealed no degenerative changes or mild degenerative changes in 61% of patients, with 39% having moderate or severe degenerative changes. Alignment of the limb was neutral in 55% of the patients, overcorrected in 32% of patients, and undercorrected in 13% of patients.

Degenerative changes on radiographs were compared with features such as gender, number of operations before the transplant, the presence of an osteotomy, HSS score and length of time that the graft remained in situ. Although some patients with severe degenerative changes had good HSS scores, on average, HSS scores decreased among patients classified as having more severe degenerative changes ($p < 0.001$; Table 5).

Doing a realignment osteotomy did not affect the degree of degenerative change in the knee or the HSS score of patients with intact grafts. The timing of realignment surgery suggested that patients who had a coincident osteotomy with grafting had an improved HSS score (Table 6). The HSS score and the degree of degenerative change were not correlated with the maintenance of an overcorrected alignment at final followup in patients with intact grafts. Gender and age at the time of index surgery were not correlated with HSS score or the degree of joint degeneration at final followup.

TABLE 5. The Average Hospital for Special Surgery Scores for Each Radiographic Grade of Degenerative Changes Shown on Final Followup in the Plateau Group

HSS Score	Radiographic Osteoarthritic Changes
8 ± 6	None
91 ± 8	Mild
85 ± 8	Moderate
61 ± 13	Severe

TABLE 6. The Functional Outcome and Survivorship Data among Patients with Realignment Osteotomy Grouped by the Timing of the Osteotomy in the Plateau Group

Osteotomy Timing	Mean HSS Score	Mean Time to Total Knee Replacement Conversion (months)
Previous osteotomy	95.0 ± 6.2	None
Coincident osteotomy	85.4 ± 11.9	115.8
Delayed osteotomy	76.8 ± 6.7	83.2

DISUSSION

The role of fresh osteochondral allografts for posttraumatic joint defects still is being defined even though encouraging mid-term to long-term results have been published.[3–5,12–14,16–19,22,23,31,34,36,45] Advances in other techniques for cartilage repair and resurfacing have reduced the role of allograft tissue transplantation to larger defects.[6–8,11,24,32,37,40] Pure chondral defects smaller than 3 cm in diameter can be treated by microfracture techniques, autologous chondrocyte transplantation, osteochondral autografts (mosaicplasty), or periosteal autografts.[6–8,24,37,39,43] Many of these techniques also may be used to treat defects extending into the subchondral bone (osteochondral defects) when they are smaller than 3 cm in diameter and 1 cm deep. Defects larger than 3 cm in diameter or 1 cm deep are more suited to osteochondral allograft transplantation because of the magnitude of cartilage and subchondral bone missing. When such a large defect exists in the weightbearing portion of the joint, patients are more likely to become disabled than those with smaller defects, who are candidates for other resurfacing procedures. Authors of previous studies compared the Short Form-36 scores of 47 patients with transplants to large articular defects to normative data from an age-matched group.[1] At an average of 12 years followup, the patients with transplants had favorable results in every category, and 93% considered their operation a success. The greatest discrepancies in the Short Form-36 scores were in the categories of physical functioning and "role physical." Despite this, these patients returned to a normal lifestyle including participation in leisure sports, but not in competitive sports.

There are several advantages in using allograft tissue to repair osteochondral defects. No morbidity exists at the harvested area because the tissue is harvested from a deceased organ donor. The exact size and shape of the osteochondral defect also may be duplicated using allograft tissue, and the use of many grafts with healing seams is obviated. Studies on the long-term viability of transplanted allograft hyaline cartilage have shown up to 50% viable

cells at 92 months after transplantation.[41] The longest confirmation of chondrocyte viability at our institute is 17 years posttransplantation of a medial femoral condyle graft done for a giant cell tumor.[35] Clinical and radiographic outcome studies with up to 10 years followup have been published showing good outcomes.[12,13,16,19,45] Disadvantages also exist with the use of osteochondral allograft tissue. A well-organized transplant program is necessary to coordinate the logistics of obtaining fresh tissue and doing the surgery within 48 hours. The surgery cannot be done on an elective basis given the uncertainty of donor availability. Disease transmission in fresh allograft tissue remains a concern despite proper screening according to the American Association of Tissue Banks guidelines.[26] Risks are described to prospective recipients as equal to those for homologous blood transfusion (human immunodeficiency virus risk of 1 in 493,000, hepatitis C risk of 1 in 103,000, hepatitis B risk of 1 in 63,000),[9,26,48] although we think that the true risk in osteochondral allografts is lower.

Chondrocyte viability in fresh allograft transplants is maintained by synovial bathing of the hyaline cartilage. Revascularization and gradual substitution of the allograft bone with host bone takes place on the osseous side of the transplant for several years depending on the size of the fragment. Cryopreservation of osteochondral fragments was attempted in the past because this diminishes the uncertainties of transplant organization and possible disease transmission. Studies on chondrocyte survival in cryopreserved articular cartilage have shown decreased cell viability after transplantation.[46,47,51,52] We have chosen to use fresh tissue despite the mentioned disadvantages, because up to 50% functioning chondrocytes within a matrix of hyaline cartilage have been shown on retrieval.[15,41]

In the current study, we were able to obtain followup on 60 of 69 patients (87%) who were a minimum of 5 years from the time of their transplantation surgery. Nine patients (15%) were lost to followup because of an international study population, and many patients were more than 10 years past the date of surgery. Despite these circumstances, we are satisfied that a sufficient number of cases was obtained to give a representative sample of osteochondral transplant patients an average of 10 years after surgery. Excellent long-term survival has been shown, with 85% (confidence interval 41%–100%) of patients surviving without additional surgery as many as 10 years after transplantation, and a projected survivorship of 74% (95% confidence interval 16%–100%) at 15 years. Of the 12 patients with greater than 15 years of followup, only four have had failed results. These results are in keeping with the findings in an earlier survivorship analysis, which predicted 71% (95% confidence interval: 60%–95%) of patients with intact grafts at 10 years.[19] However, this latter figure is based on a patient population in which femoral and tibial sided transplants were done. Of equal importance is the mean 10-year HSS score of 83 points, with 84% of patients reporting good or excellent overall outcomes. The mean score for pain was 28 points (mild pain for which the patients required occasional analgesics) and most patients were able to walk farther than 1 mile with few problems. Again, these results are in keeping with those previously reported.[5,19,34]

In past studies on fresh osteochondral transplantation to the tibia and femur, it was determined that bipolar grafts, ligamentous instability of the knee, and grafts for osteoarthritis or steroid induced osteonecrosis all lead to poor outcomes.[4,5,31,34,41] In the current study, we only studied monopolar transplants, because bipolar transplants are no longer done. We think that the presence of disease on both sides of a given compartment is a contraindication to fresh allograft transplantation. We also consider the presence of arthritis (which in most patients will involve both sides of the joint) a contraindication for this treatment. The graft in the one patient in this study in whom a transplant was accomplished for osteoarthritis failed at just more than 6 years. No association was found between the remaining etiologies and graft failure or clinical failure on long-term followup.

Limb alignment was found in an early study to have a significant bearing on patient outcomes.[41] Realignment of the extremity such that force transmission occurred through the knee compartment opposite the transplant was found to improve outcomes. For approximately 20 years, we have done realignment optimally at the time of transplantation. The success of this practice is seen in the current study, in that patients needing realignment surgery had equal outcomes to those who did not need realignment surgery.

In the current study, we have shown encouraging results achievable with fresh allograft transplantation to the femoral condyle. At 10 years followup, 85% of the grafts have survived, and most patients report good function. This procedure remains an important treatment option in addressing large osteochondral defects in young, active individuals.

We reviewed the minimum 5-year results of fresh osteochondral allografts for posttraumatic, unipolar tibial plateau lesions in young, high-demand patients. All patients previously had tibial plateau fractures that had been treated by conventional means. At the time of referral, many patients had been considered for knee arthroplasty. Although there have been recent advances in other domains of biologic reconstruction for cartilage lesions, there does not seem to be an alternative solution for plateau defects as large as 3 cm in diameter and 1 cm deep.

We made use of osteotomies in 58% of patients when the weightbearing axis passed through the compartment that was to receive the allograft. The osteotomy decreased the force that passed through the graft during weightbearing activities. Among patients with osteotomies, improved results were seen when realignment preceded or coincided with the allograft surgery. In patients with intact grafts, improved HSS scores were noted with early realignment (Table 6). Among patients with failed grafts, conversion to knee arthroplasty was delayed by early osteotomy.

Of the 58% of patients with osteotomies 73% were done coincident with grafting. We think that when an adjunctive osteotomy is required, it should be done at the same time as the transplantation procedure. Delayed osteotomy should be reserved as a salvage procedure for a deteriorating graft when the mechanical axis passes through the grafted compartment in very young patients. Among patients with intact grafts, the mechanical axis remained overcorrected in 32% of patients, neutral in 55% of patients, and undercorrected in 13% of patients. Noting that all misaligned limbs in the study had corrective osteotomy in this study, on final review we could not demonstrate a difference in HSS scores or joint degeneration among intact grafts on the basis of whether an osteotomy was done.

A trend indicated better survivorship in patients who had meniscal transplantation along with the osteochondral allograft. Patients with meniscal allografts who required conversion to total knee replacement required arthroplasty at an average of 10.4 years in comparison with 7.1 years in patients without a meniscal transplant ($p = 0.08$). A selection bias in the study favored the group that did not receive a meniscal transplant because only patients with the most damaged menisci (often with corresponding focal chondral damage to the femoral condyle) had meniscal transplant. Before a review of this data, we had a strong predilection for debridement and retention of the host meniscus. We now think that increased use of meniscal allografts is warranted.

Good to excellent results on the basis of HSS scores were found in 86% of patients at an average of 12 years followup (range, 5–24 years). Only 39% of knees had moderate to severe degenerative changes at final followup. A correlation between severe degenerative changes and HSS score was identified. The HSS score did not degrade over time in the absence of degenerative changes.

Conversion to total knee replacement is a salvage procedure for the deteriorating graft. It occurred in ⅓ of the patients an average of 10 years after the allograft surgery. Conversion to total knee replacement many years after an allograft does not indicate failure of the procedure. Kaplan-Meier survivorship statistics showed a survivorship of 80% (10 years) and 65% (15 years). A trend revealed increased survivorship ($p = 0.008$) among patients who had meniscal transplantation in conjunction with osteochondral grafting. We think that procedure successfully provides an enduring stable and functional knee in young, high-demand patients. The presence of the tibial allograft did not make knee arthroplasty technically more difficult. We showed that in relatively young patients with a large tibial defect after a plateau fracture that has failed conventional treatment, osteochondral allograft implantation could delay total knee arthroplasty for a long time while providing the patient with functional use of the knee.

References

1. Agnidis Z, Stimec J, Krajbich J, Hutchison CR, Gross AE: Health-related quality-of-life following fresh osteochondral allograft of the knee: A minimum five year follow-up. J Bone Joint Surg 81B(Suppl 1):106, 1999.
2. Aubin PP, Cheah HK, Davis AM, Gross AE: Long-term followup of fresh osteochondral allografts for posttraumatic knee defects. Clin Orthop 391:318–327, 2001.
3. Bakay A, Csonge L, Papp G, Fekete L: Osteochondral resurfacing of the knee joint with allograft. Clinical analysis of 33 cases. Int Orthop 22:277–281, 1998.
4. Bayne O, Langer F, Pritzker KP, Houpt J, Gross AE: Osteochondral allografts in the treatment of osteonecrosis of the knee. Orthop Clin North Am 16:727–740, 1985.
5. Beaver RJ, Mahomed M, Backstein D, et al: Fresh osteochondral allografts for post-traumatic defects in the knee: A survivorship analysis. J Bone Joint Surg 74B:105–110, 1992.
6. Blevins FT, Steadman JR, Rodrigo JJ, Silliman J: Treatment of articular cartilage defects in athletes: An analysis of functional outcome and lesion appearance. Orthopedics 21:761–768, 1998.
7. Bobic V, Carter T: Osteochondral autologous graft transfer. Oper Tech Sports Med 8:168–178, 2000.
8. Brittberg M, Lindahl A, Nilsson A, et al: Treatment of deep cartilage defects in the knee with autologous chondrocyte transplantation. N Engl J Med 331:889–895, 1994.
9. Buck BE, Malinin TI, Brown MD: Bone transplantation and human immunodeficiency virus: An estimate of risk of acquired immunodeficiency syndrome (AIDS). Clin Orthop 240:129–136, 1989.
10. Buckwalter JA, Lohmander S: Operative treatment of osteoarthrosis: Current practice and future development. J Bone Joint Surg 76A:1405–1418, 1994.
11. Buckwalter JA, Mankin HJ: Articular cartilage repair and transplantation. Arthritis Rheum 41:1331–1342, 1998.
12. Bugbee WD, Convery FR: Osteochondral allograft transplantation. Clin Sports Med 18:67–75, 1999.
13. Chu CR, Convery FR, Akeson WH, Meyers M, Amiel D: Articular cartilage transplantation: Clinical results in the knee. Clin Orthop 360:159–168, 1999.
14. Convery FR, Meyers MH, Akeson WH: Fresh osteochondral allografting of the femoral condyle. Clin Orthop 273:139–145, 1991.
15. Czitrom AA, Keating S, Gross AE: The viability of articular cartilage in fresh osteochondral allografts after clinical transplantation. J Bone Joint Surg 72A:574–581, 1990.
16. Fitzpatrick PL, Morgan DA: Fresh osteochondral allografts: A 6–10-year review. Aust N Z J Surg 68:573–579, 1998.
17. Flynn JM, Springfield DS, Mankin HJ: Osteoarticular allografts to treat distal femoral osteonecrosis. Clin Orthop 303:38–43, 1994.
18. Garrett JC: Fresh osteochondral allografts for treatment of articular defects in osteochondritis dissecans of the lateral femoral condyle in adults. Clin Orthop 303:33–37, 1994.
19. Ghazavi MT, Pritzker KP, Davis AM, Gross AE: Fresh osteochondral allografts for post-traumatic osteochondral defects of the knee. J Bone Joint Surg 79B:1008–1013, 1997.
20. Gross AE, Hutchison CR: Realignment osteotomy of the knee-part

1:distal femoral varus osteotomy for osteoarthritis of the valgus knee. Oper Tech Sports Med 8:122–126, 2000.
21. Gross AE, Hutchison CR: Realignment osteotomy of the knee-part 2: Proximal valgus tibial osteotomy for osteoarthritis of the varus knee. Oper Tech Sports Med 8:127–130, 2000.
22. Gross AE, McKee NH, Pritzker KP, Langer F: Reconstruction of skeletal deficits at the knee: A comprehensive osteochondral transplant program. Clin Orthop 174:96–106, 1983.
23. Gross AE, Silverstein EA, Falk J, Falk R, Langer F: The allotransplantation of partial joints in the treatment of osteoarthritis of the knee. Clin Orthop 108:7–14, 1975.
24. Hangody LK, Karpati Z: Arthroscopic autogenous osteochondral mosaicplasty for the treatment of femoral condylar articular defects. Knee Surg Sports Traumatol Arthrosc 4:262–269, 1997.
25. Insall JN, Joseph DM, Msika C: High tibial osteotomy for varus gonarthrosis: A long-term followup study. J Bone Joint Surg 66A:1040–1048, 1984.
26. Jacobs NJ: Establishing a Surgical Bone Bank. In Fawcett K, Barr HR (eds). Tissue Banking. Arlington, American Association of Blood Banks 67–96, 1987.
27. Kaplan EL, Meier P: Nonparametric estimation from incomplete observations. J Am Stat Assoc 53:457–481, 1958.
28. Langer F, Czitrom A, Pritzker KP, Gross AE: The immunogenicity of fresh and frozen allogeneic bone. J Bone Joint Surg 57A:216–220, 1975.
29. Langer F, Gross AE: Immunogenicity of allograft articular cartilage. J Bone Joint Surg 56A:297–304, 1974.
30. Langer F, Gross AE, West M, Urovitz EP: The immunogenicity of allograft knee joint transplants. Clin Orthop 132:155–162, 1978.
31. Locht RC, Gross AE, Langer F: Late osteochondral allograft resurfacing for tibial plateau fractures. J Bone Joint Surg 66A:328–335, 1984.
32. Mandelbaum BR, Browne JE, Fu F, et al: Articular cartilage lesions of the knee. Am J Sports Med 26:853–861, 1998.
33. Matthews LS, Goldstein SA, Malvitz TA, Katz BP, Kaufer H: Proximal tibial osteotomy: Factors that influence the duration of satisfactory function. Clin Orthop 229:193–200, 1988.
34. McDermott AG, Langer F, Pritzker KP, Gross AE: Fresh small-fragment osteochondral allografts: Long-term followup study on first 100 cases. Clin Orthop 197:96–102, 1985.
35. McGovern BM, Pritzker KPH, Shasha N, Price J, Gross AE: Long term chondrocyte viability in a fresh osteochondral allograft. Am J Knee Surg 15:97–100, 2002.
36. Meyers MH, Akeson W, Convery FR: Resurfacing of the knee with fresh osteochondral allograft. J Bone Joint Surg 71A:704–713, 1989.
37. Minas TP: Autologous chondrocyte transplantation. Oper Tech Sports Med 8:144–157, 2000.
38. Minas T: Clinical methods of cartilage repair: Autologous chondrocyte implantation for focal chondral defects of the knee. Clin Orthop 1:349–361, 2001.
39. Moran ME, Kim HK, Salter RB: Biological resurfacing of full-thickness defects in patellar articular cartilage of the rabbit: Investigation of autogenous periosteal grafts subjected to continuous passive motion. J Bone Joint Surg 74B:659–667, 1992.
40. Newman AP: Articular cartilage repair. Am J Sports Med 26:309–324, 1998.
41. Oakeshott RD, Farine I, Pritzker KP, Langer F, Gross AE: A clinical and histologic analysis of failed fresh osteochondral allografts. Clin Orthop 233:283–294, 1988.
42. O'Driscoll SW: The healing and regeneration of articular cartilage. J Bone Joint Surg 80A:1795–1812, 1998.
43. O'Driscoll SW, Salter RB: The induction of neochondrogenesis in free intra-articular periosteal autografts under the influence of continuous passive motion: An experimental investigation in the rabbit. J Bone Joint Surg 66A:1248–1257, 1984.
44. Parrish FF: Allograft replacement of all or part of the end of a long bone following excision of a tumor. J Bone Joint Surg 55A:1–22, 1973.
45. Salai M, Ganel A, Horoszowski H: Fresh osteochondral allografts at the knee joint: Good functional results in a followup study of more than 15 years. Arch Orthop Trauma Surg 116:423–425, 1997.
46. Schachar N, McAllister D, Stevenson M, Novak K, McGann L: Metabolic and biochemical status of articular cartilage following cryopreservation and transplantation: A rabbit model. J Orthop Res 10:603–609, 1992.
47. Schachar NS, McGann LE: Investigations of low-temperature storage of articular cartilage for transplantation. Clin Orthop 208:146–150, 1986.
48. Schreiber GB, Busch MP, Kleinman SH, Korelitz JJ: The risk of transfusion-transmitted viral infections. The Retrovirus Epidemiology Donor Study. N Engl J Med 334:1685–1690, 1996.
49. Shasha N, Krywulak S, Backstein D, Pressman A, Gross AE: Long-term follow-up of fresh tibial osteochondral allografts for failed tibial plateau fractures. J Bone Joint Surg 85A(Suppl 2):33–39, 2003.
50. Steadman RJ, Rodkey WG, Singleton SB, Briggs KK: Microfracture technique for full thickness chondral defects: Technique and clinical results. Oper Tech Orthop 7:300–305, 1997.
51. Stevenson S, Dannucci GA, Sharkey NA, Pool RR: The fate of articular cartilage after transplantation of fresh and cryopreserved tissue-antigen-matched and mismatched osteochondral allografts in dogs. J Bone Joint Surg 71A:1297–1307, 1989.
52. Tomford WW, Duff GP, Mankin HJ: Experimental freeze-preservation of chondrocytes. Clin Orthop 197:11–14, 1985.
53. Volkov M: Allotransplantation of joints. J Bone Joint Surg 52B:49–53, 1970.