Fresh Osteochondral Allografting of the Femoral Condyle

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Fresh osteochondral shell allografting is conceived as an interim response to the localized loss of articular cartilage in young patients for whom there is no reasonable alternative after conservative procedures have failed. The concept is not new and has been investigated extensively in *in vivo* animal investigations. The functional and anatomic results of these studies, however, have been consistently unsatisfactory because of technical deficiencies and supposed immunogenic responses. The results of early clinical studies were variable, and despite more recent clinical work, the procedure has been considered at least investigational by some. The purpose of this study is to retrospectively review a series of patients treated with osteochondral allografting of the femoral condyle with particular emphasis on those done more than five years ago. No tissue-typing blood-group matching or gender distinction was made and immunosuppressant agents were not used. Size matching of the donor and recipient were essential to provide an orthotopic graft. Twelve knees were operated on more than five years ago. Of these twelve, three are not available for review. Nine knees have been observed for an average of 66 months and eight are rated good or excellent by a standardized rating scale. One knee rated poor seems to be the result of a technical deficiency. Since 1983, 37 fresh osteochondral allografts of the femoral condyle have been performed in 36 patients. Twenty-five of these have been performed in the last five years and the results to date are summarized.

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Fresh osteochondral shell allografting has been introduced as an alternative to hemiarthroplasty or total arthroplasty in the young patient with localized osteochondral defects. Defects caused by osteochondritis dissecans, osteochondral fractures, and localized avascular necrosis that have failed more conservative treatment, *e.g.*, arthroscopic drilling, can be considered for allografting. Although osteochondral allografting has been done for unicompartmental osteoarthrosis in which both surfaces were replaced (bipolar), the results to date are poor.[11,18,21]

There are five fundamental factors that must be addressed in a study of fresh osteochondral allografting: mechanical factors, risk of an immunogenetic response, risk of transmitted infection, possibility of bone resorption leading to collapse of the cartilage, and survival of the articular cartilage. Each of these considerations are of significant consequence.

Early in these efforts, it was apparent that technical deficiencies in the performance of the procedure that caused mechanical dysfunction resulted in clinical failure.[1,2,12,15,19–23] From this early work, it is clear that the graft must be orthotopic, that a perfect fit in the host bed be accomplished, and that firm fixation be achieved either by press fit or by a press fit and supplemental fixation. In addition, the joint must be stable. Ligamentous laxity may significantly compromise the result.[9]

Articular cartilage has been assumed to be an immunologically privileged tissue. Isolated chondrocytes contain transplantation antigens and are immunogenic.[15,16,24] If, however, the articular cartilage is intact, it is thought that articular surface grafts do not sensitize recipient animals.[15] Marrow elements of fresh bone, conversely, are immunogenic, and experimental allografting of articular cartilage in animals has provoked an early inflammatory reaction with panus formation[24] and late degenerative changes that were attributed to an immune response.[5,7,10,28]

The purpose of this study was to retrospectively evaluate a series of patients treated with osteochondral allografting of the femoral condyle with particular emphasis on those performed more than five years ago.

MATERIAL AND METHODS

Since 1983, 37 fresh osteochondral shell allografts of the femoral condyle in 36 patients have been performed. There were 25 females and 11 males whose ages ranged from 15 to 68 (mean, 35) at the time of surgery. Twenty-three patients had traumatic osteochondral defects (the most common indication), eight patients had osteochondritis dissecans, and six had steroid-induced avascular necrosis of the femoral condyle. In this group of 36 patients, 20 were treated previously with open arthrotomies and an additional 59 arthroscopies were performed, an average of 2.1 previous-operative procedures per patient.

Twenty-five patients had allografting of the femoral condyle, 17 medial, and 11 lateral; Eleven patients had allografting at additional sites in the same knee—the tibial plateau (bipolar) in six, the patella in four, and in one knee both condyles were treated. Because of previous injury, the anterior cruciate ligament was absent in three knees. Initially, the procedures were performed or supervised by the senior author. Subsequently, as the indications were expanded, two additional surgeons became involved.

The size of the allografts was variable ranging from approximately 1 × 1 cm to 2 × 6 cm. The thickness of the subchondral bone was kept to within 5 mm and was subjected to a high-pressure saline lavage before implantation. All patients were placed in a continuous passive motion machine in the recovery room, discharged when independent on crutches, and ambulated nonweight bearing for 12 weeks. A few patients were kept nonweight bearing after 12 weeks, when the roentgenographs showed delayed graft–host incorporation.

Before June 1989, the allografts were press fitted into the surgically fashioned site and occasionally supplemented with screws when necessary. Since that time, all of the allografts have been press fitted and further secured with orthosorb (Johnson & Johnson Orthopaedics, New Brunswick, New Jersey) biodegradable polydioxanon pins (Fig. 1). The details of procurement and the surgical technique have been presented elsewhere,[21] but it is essential to point out that all grafts were collected according to the criteria of the American Association of Tissue Banks.[3]

FIG. 1. The residual defect (arrow) created by placement of the biodegradable pin and the surrounding allograft ten months postoperatively.

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Follow-up evaluations were done at three-month intervals for the first year and, when possible, annually thereafter. Because of travel distance, it was frequently necessary to resort to telephone interviews and outside roentgenographs for long-term follow-up evaluation. A clinical rating system that assessed pain, function, and range of motion was used. This system, a modification of the Hip rating scale of Merle d'Aubigne and Postel, has been published previously.[21]

Figure 2A shows a characteristic osteochondral defect in the lateral femoral condyle. This 20-year-old man denied previous trauma, had the spontaneous onset of pain four-to-five years previously, was disabled for any athletic or heavy activities, and had been treated with four unsuccessful arthroscopic procedures.

Figure 2B demonstrates the extent of the lesion and the allograft in place. The dimensions of the allograft were 2.2 cm-by-3.2 cm. No supplemental fixation was used. Figure 2C is the most recent roentgenographs obtained 33 months after allografting. At the last follow-up visit (33 months), the patient had normal function, no pain, and was skiing on snow and water.

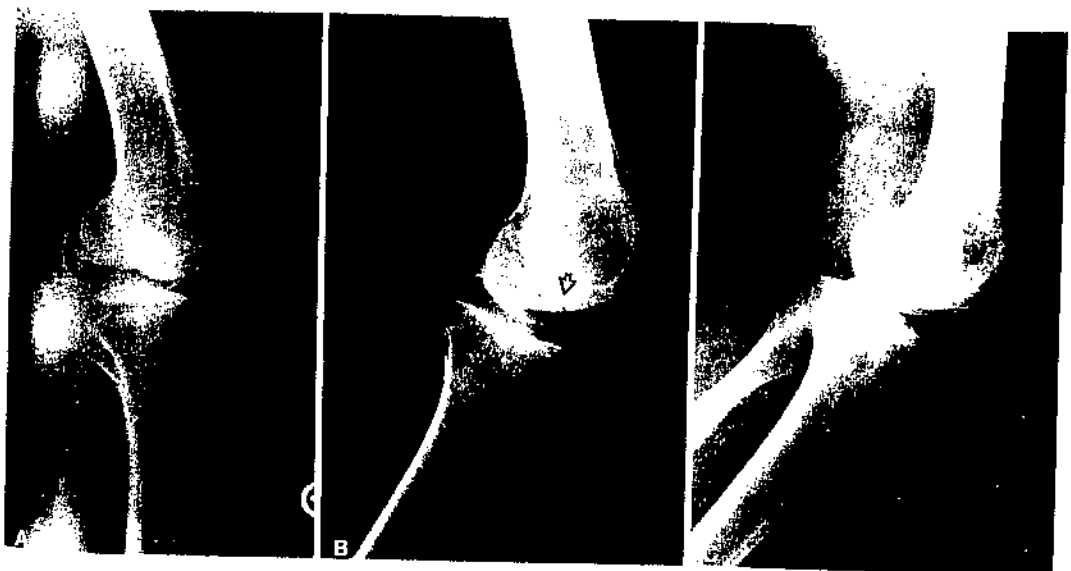
In the beginning, the grafts were done within 72 hours of collection. More recently, the time has been extended to seven days. Recent work in the research laboratory has demonstrated preservation of the histologic, mechanical, and chemical characteristics of articular cartilage for up to 28 days. In this study, the articular cartilage of the tibial plateau was collected from canines and stored in culture media at 4° that was changed twice weekly. Biochemical and biomechanical evaluation were performed three, seven, 14, and 28 days after collection.[14]

The grafts in the clinical series were stored in Ringers lactate solution containing 1 gr of keflin (cephalothin) and 10 mg of gentamicin per letter of solution at 4° until used. No tissue typing or blood group matching was done and immunosuppressant agents were not used in the clinical series.

RESULTS

Twelve knees in 11 patients were treated more than five years ago (Table 1). Two patients have died in the interim of their primary disease. Both had steroid-induced avascular necrosis of the femoral condyle and were said to be functioning well at the last follow-up clinic visit, one and four years after transplantation, respectively. One allograft was unsuccessful and was redone. This was the first procedure done in San Diego, and there was a gross error in the size of the available allograft.

Thus, there remain nine knees in eight patients who have been observed from five to six years (average, 66 months) and eight are



FIGS. 2A–2C. (A) Preoperative lateral roentgenograph. (B) Lateral roentgenograph immediately postoperatively. (C) Lateral roentgenograph 33 months postoperatively.

TABLE 1. Twelve Consecutive Femoral Condylar Allografts

Diagnosis	*Previous Surgery*	*Site*	*Follow-Up Months*	*Comments*
OD	Arthrotomy x1	LFC/LTP	24	Bipolar—size mismatch; repeat allograft
OD	Arthrotomy x2 Arthroscopy x1	LFC	77	Runs 25 miles/week
AVN	0	MFC	48	Deceased four years postoperative
OD	Arthroscopy x1	MFC	60	Bikes a lot; avoids stairs; patellar symptoms
Traumatic	Arthrotomy x3	MFC/MTP	71	"Perfect;" unlimited function; bipolar and meniscus
Traumatic	Arthroscopy x1	LFC	69	No problems working (construction)
AVN	0	LFC	69	First of bilateral; opposite side poor; See Figure 3B
Traumatic	Arthrotomy x1	MFC	66	Plays tennis; rides; bikes
Traumatic	Abrasion Arthroplasty x1	MFC	60	Occasional ache
AVN	0	MFC	61	Technical deficiency; See Figure 3A
AVN	0	LFC	12	Deceased; leukemia one year postoperative
OD	Arthroscopy x2	MFC	64	No restrictions

OD, osteochondritis dissecans; AVN, avascular necrosis; LFC, lateral femoral condyle; LTP, lateral tibial plateau; MFC, medial femoral condyle; MTP, medial tibial plateau.

rated excellent or good, with return to running, racquet sports, and construction work. One knee is rated poor (Fig. 3A). The opposite knee, in which allografting was done a year earlier, remains excellent (Fig. 3B).

Subsequently, there have been three additional unsuccessful allografts in the 37 knees treated to date. All three were young females with traumatic osteochondral defects and all three had no anterior cruciate ligament because of previous trauma. These are the only anterior cruciate deficient knees in the series. One of these patients has been treated with prosthetic knee arthroplasty. The other two patients have had arthroscopic procedures but are still doing poorly. In the knee that was unsuccessful and subsequently was treated with knee arthroplasty, bipolar allografting had been performed. The femoral allograft was said by the operating surgeon to appear normal, whereas the tibial allograft had degenerated, which would suggest mechanical rather than immune mechanisms as the cause of failure.

Figure 4 is the 64-month postoperative roentgenograph of a 31-year-old women with a preoperative diagnosis of osteochondritis dissecans. She had previously had two arthroscopic procedures, initially drilling and removal of loose bodies, subsequently a repeat procedure to remove additional loose bodies. At the time of surgery, her primary complaint was pain with ambulation and inability to walk long distances. The patient has no pain and a full range of motion. The graft is incorporated, there is an area of what appears to be avascular necrosis and some resorption within the graft, but the joint space is maintained and there is no gross collapse.

Eight knees were operated on two to five years ago. Five are rated good or excellent, although one patient required removal of screws used to secure an associated patellar allograft before achieving this rating. Two knees have failed because of anterior cruciate deficiency and one 61-year-old women is rated only fair because of the development of early degenerative arthritis. This allograft was

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FIGS. 3A AND 3B. (A) Lateral roentgenograph taken 69 months postoperatively of the knee that is rated poor. The step off between the graft and the postsubchondral bone is indicated (arrow). (B) Lateral roentgenograph of the opposite knee done one year earlier that is rated excellent.

performed for an isolated traumatic defect of the medial femoral condyle.

Seventeen knees have been operated on in the past two years. Twelve of these knees are progressing well at various lengths of follow-up evaluation. Five have had problems. One is the third unsuccessful allograft in a knee without an anterior cruciate ligament, and one has to be rated poor because of severe chondromalacia of the patella that possibly should have been grafted at the time the traumatic defect of the medial femoral condyle was treated. One knee was reoperated to elevate a depressed junction between the allograft and host articular cartilage, very similar to the off set demonstrated in Figure 3B, and the patient has returned to work. Two knees were treated arthroscopically after the allografting. One is now rated excellent and, in the second, the follow-up period is too short to evaluate.

In the total series, there have been no wound infections and local or systemic signs or symptoms to suggest an immune response. All of the failures seemed to be of mechanical origin.

DISCUSSION

This study, like many previous, again demonstrates the need for technical proficiency in performing fresh osteochondral shell allografting. The use of biodegradable pins is a recent addition to the authors' surgical technique and is technically satisfying, but, to date, they cannot demonstrate any specific benefit.

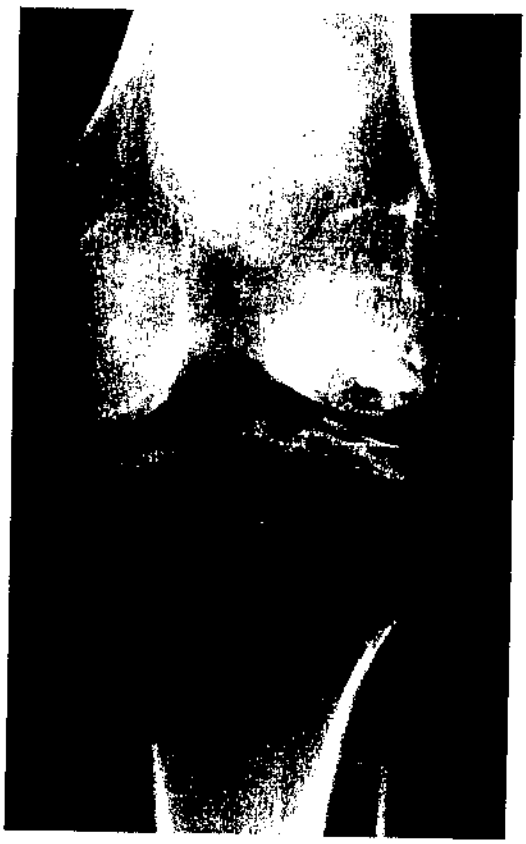

FIG. 4. Anteroposterior roentgenograph of an allograft of the lateral femoral condyle done five years previously.

It is, however, clear that a perfect press fit, with the allograft slightly proud (1–2 mm), is a crucial prerequisite. If a cancellous autograft is used to fill a defect below the allograft, the shell is elevated 2–3-mm above the surrounding articular cartilage.

The anterior cruciate ligament was absent in three knees and the outcome unsuccessful. In one of the three, a simultaneous allograft reconstruction was performed. It is now believed that a stable knee is essential and that anterior cruciate or any other ligamentous deficiency be successfully reconstructed, before or simultaneously with osteochondral allografting.

The possibility of an immunogenic response leading to late degeneration of articular cartilage has been suggested in many previous studies. Elves and Ford[8] demonstrated serum cytoxic antibodies in sheep, after shell and block allografts. This suggested the need for crossmatching of donor and recipient. More recently, studies of hemi-joint allografts (proximal one fourth of the radius in canines) demonstrated an intraarticular and systemic immune response.[26] The immune response, however, could be modulated by tissue-antigen matching.[27]

In this series, tissue typing, or blood group matching, was not done, and no immunosuppressant agents were used. The allograft bone is, however, kept to a minimal thickness (*i.e.*, 5 mm), and the bone is vigorously lavaged before transplantation. The absence of late degeneration of articular cartilage (more than five years) in eight of nine available knees would seem to suggest that the osteochondral shell allograft, as described, does not stimulate an immune response. Further support for this concept is provided by the demonstration of viable chondrocytes in human osteochondral allografts, as long as six years after transplantation.[6] In one of the patients, bilateral procedures were performed. One is rated excellent and one rated poor. The poor result seems directly related to a technical deficiency, rather than late degeneration, or an immune response.

In the beginning, the transplants were performed within 72 hours of collection. On the basis of work in the authors' laboratory[14] and the work of others,[17] the time was extended to seven days. In Toronto, the storage time is a minimum of 24 hours.[11] Most recently, a study of osteochondral shell allografts in goats, in which the allografts were stored in a culture media for 14 days before transplantation at 4°, demonstrated only a 25% (two of eight) success rate, 12 months postoperatively.[25] The allograft failures were caused by bone resorption and cartilage degeneration. Of more significance to the question of storage was the marked reduction of chondrocyte viability with time, as determined by uptake of $^{35}SO4$. From Day 1 to Day 7, the number

of viable chondrocytes dropped from 13,571 (CPM/100 ul of digest) to 669 at Day 7, and to 256 by Day 14. Clinical differences that have occurred as a result of extending the permissable storage time have not been identified, but the above study demonstrates that this remains an unanswered question and that possibly the current protocol should be revised.

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