FRESH OSTEOCHONDRAL ALLOGRAFTS FOR POST-TRAUMATIC DEFECTS IN THE KNEE

A SURVIVORSHIP ANALYSIS

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Fresh osteochondral allografts were used to repair post-traumatic osteoarticular defects in 92 knees. At the time of grafting, varus or valgus deformities were corrected by upper tibial or supracondylar femoral osteotomies. A survivorship analysis was performed in which failure was defined as the need for a revision operation or the persistence of the pre-operative symptoms.

There was a 75% success rate at five years, 64% at ten years and 63% at 14 years. The failure rate was higher for bipolar grafts than for unipolar and the results in patients over the age of 60 years were poor. The outcome did not depend on the sex of the patient and the results of allografts in the medial and lateral compartments of the knee were similar. Careful patient selection, correction of joint malalignment by osteotomy, and rigid fixation of the graft are all mandatory requirements for success.

We recommend this method for the treatment of post-traumatic osteochondral defects in the knees of relatively young and active patients.

The reconstruction of defects of bone and articular cartilage in the weight-bearing joints of relatively young, active patients remains a difficult problem. Knee prostheses are subject to heavy loads and frequently loosen. A more biological method of replacing articular cartilage and subchondral bone may be preferred in these patients.

Fresh cadaveric osteochondral allografts were first used in man by Lexer in 1908. In a follow-up review in 1925, he reported 50% successful results. Following much basic research in immunology and transplantation during the 1960s, there was a resurgence of interest in the transplantation of bone and cartilage and several authors reported encouraging results (Volkov 1970; Ottolenghi

1972; Parrish 1973). The establishment of large institutional bone banks allowed further research into the biology of allografts and the demand for them grew as limb-salvage surgery for malignant bone tumours became possible and as failed total joint replacements presented with secondary bone deficiencies.

We have performed osteochondral allografts for a variety of diagnoses. However, after a review of our first 100 cases it appeared that the best results were obtained in the reconstruction of post-traumatic defects in the knee. Osteochondritis dissecans became only a relative indication and osteoarthritis and osteonecrosis are now thought to be relative contra-indications (McDermott et al 1985; Zukor, Oakeshott and Gross 1989).

We report the survivorship analysis of a series of fresh, osteocartilaginous allografts of the knee performed for the repair of post-traumatic defects.

PATIENTS AND METHODS

We operated on 99 knees in 98 patients. Seven patients were excluded because they could not be contacted by telephone and did not have sufficient data in their files for calculation of knee scores. Of the remaining 91 patients (92 knees), 46 were clinically reviewed. In 25 cases this was not possible and these patients were contacted by telephone and questionnaires were com-

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Fig. 1a

Figure 1a - Diagram of the operation performed for an osteoarticular defect in the weight-bearing portion of the lateral tibial plateau which has produced a genu valgum deformity; b) the knee of a 26-year-old woman with a malunited lateral tibial plateau fracture; c) immediately after replacement of the deficient lateral tibial plateau with an allograft and distal femoral varus osteotomy; d) five years later the allograft has united to the host with minimal subsidence. The implant has been removed from the femur. The joint space is well preserved but early degenerative changes are present.

Fig. 1b

Fig. 1c

Fig. 1d

pleted. Sixteen patients who could not be contacted by telephone but whose data were complete until the time of last review were included in the survivorship analysis up to the date of that review. There were five deaths due to unrelated causes and the data in these cases were treated similarly.

Each knee was scored using a modified HSS knee scoring system (Zukor et al 1989). We defined failure as less than ten points improvement after operation, or the need for a revision operation, other than for removal of implants, or the patient's opinion that the knee was worse than before the allograft procedure.

Collection of grafts. Fresh osteochondral allografts were procured according to the procedures established by the American Association of Tissue Banks (Friedlander and Mankin 1979; Tomford and Mankin 1987). The donors chosen were less than 30 years old in order to maximise cartilage quality. The grafts were procured under strict aseptic precautions, within 24 (preferably 12) hours of death. The entire joint was excised, preserving the joint capsule and ligaments. After taking cultures for bacteriology, fungi and mycobacteria, the joint was immersed in sterile Ringer's solution containing 1 g/l of cefazolin

and 50 000 units/l of bacitracin and was sealed within a container. The container was triple wrapped in towels and sterile plastic bags and stored at a temperature of +4°C.

Histocompatibility testing was not performed, nor was immunosuppression employed after implantation. The appropriate recipient was a patient of the same sex who required approximately that size of allograft. The allografts were always performed within 12 to 24 hours of graft procurement.

Pre-operative planning. It is essential to correct joint malalignment prior to or at the time of implantation of the allograft. This should not be done by using the allograft to build up the joint surface (McDermott et al 1985; Oakeshott et al 1988; Zukor et al 1989). Varus deformities should be corrected by proximal tibial valgus osteotomy and valgus deformities by distal femoral varus osteotomy (McDermott et al 1988).

Preparation and implantation of the allograft. Usually two surgical teams are employed, one to prepare the allograft and the other to perform any realignment procedure and prepare the graft bed.

An anterior midline incision is preferred and,

Fig. 2a

Fig. 2b

Fig. 2c

Figure 2a – Diagram of the operation performed for an osteoarticular defect in the weight-bearing portion of the medial femoral condyle which has produced a genu varum deformity; b) the knee of a 40-year-old woman with a post-traumatic defect in the weight-bearing portion of the medial femoral condyle; c) nine years after osteochondral allografting and proximal tibial osteotomy.

Fig. 3

Age distribution of 91 patients who underwent fresh osteochondral allografts for post-traumatic defects of the knee.

depending upon the site of the joint defect, a medial or lateral parapatellar arthrotomy is performed. The meniscus is inspected, and if at all possible, it is preserved or repaired. If it is irreparably damaged, it is removed and a donor meniscus is implanted with the allograft. In tibial allografts the meniscus is left attached to the donor plateau and in femoral allografts, the capsular attachments of the meniscus to the femur are retained. In both cases the meniscus is sutured to the host capsule. Bipolar grafts are those in which both the tibial and the femoral condyle of one compartment are replaced.

The most commonly encountered defect is in the weight-bearing part of the lateral tibial plateau, resulting in a genu valgum deformity. In such a case the damaged articular surface of the tibia is excised and 'squared off' down to healthy, bleeding cancellous bone. The corresponding segment of the donor joint is resected and trimmed to match the defect in the recipient bone as closely as possible. A tight fit is desirable. If a meniscus is to be implanted as well, three or four absorbable

mattress sutures are placed in its periphery to fix it to the capsule of the host. These sutures are tied after the graft has been fitted.

The allograft is rigidly fixed to the tibia with AO 4.0 mm spongiosa screws. It is important to place the screws well away from the articular cartilage and in sites not likely to cause impingement problems (Fig. 1).

If there is a varus deformity of the knee with destruction of the medial femoral condyle, we perform proximal tibial valgus osteotomy with osteochondral allograft replacement of the medial femoral condyle (Fig. 2). We have used a closing-wedge osteotomy, 2 cm distal to the joint, with elevation of the tibial tubercle (Maquet 1976; Putnam, Mears and Fu 1985).

As with the tibial plateau graft, care is taken to obtain an accurate press-fit to the bed in the femoral condyle and the graft is rigidly fixed using AO techniques. Rigid fixation is necessary to allow the use of continuous passive motion postoperatively.

Bipolar grafts are those in which both the tibial and the femoral condyle of one compartment are replaced.

Postoperative management. Continuous passive motion is instituted immediately after the operation to prevent intra-articular adhesions and to optimise cartilage nutrition. Patients are allowed to walk, partial weight-bearing, as soon as the suction drains are removed. Partial weight-bearing is maintained for at least a year by the use of an ischial-bearing long-leg orthosis.

RESULTS

There were a total of 92 grafts performed in 91 patients with an average follow-up of 68 months (median 79, range four to 174). There were 51 males and 40 females with an average age of 41.9 years (median 46, range 17 to 75). Their age distribution is shown in Figure 3.

A list of postoperative complications is shown in

Table I. Since introducing continuous passive motion, stiffness has not been a problem. Details of the procedures used in the 13 cases that have been revised are given in Table II.

Life-table analysis (Kaplan and Meier 1958) shows that, five years after transplantation, 75% (95% confidence interval 66 to 83) of cases were rated clinically as successes. At ten years and 14 years the clinical success rate was 64% (95% confidence interval 54 to 74) (Fig. 4).

Log-rank analysis, used to compare the survival rates of unipolar and bipolar grafts, showed a trend towards a higher success rate in the unipolar grafts (2-tailed $p = 0.09$, Fig. 5). We therefore assessed other factors in the unipolar group alone. A comparison

Fig. 4

Survivorship graph of 92 allografts of the knee.

Fig. 5

Survivorship graphs of unipolar and bipolar allografts.

between male and female patients with unipolar grafts showed no significant difference (2-tailed $p = 1.00$, Fig. 6). There was no difference between the clinical success rate of grafts performed on the tibia and those performed on the femur (2-tailed $p = 0.49$, Fig. 7) nor between grafts on the medial side of the joint and those on the lateral side (2-tailed $p = 1.00$, Fig. 8).

Taking both unipolar and bipolar cases, there was a trend for grafts performed in patients aged 60 years or more to do worse than those in younger patients (2-tailed $p = 0.08$, Fig. 9). However, the proportion of bipolar grafts was greater in the older group (6/12) than in the younger (13/80) indicating more severe damage in the former.

DISCUSSION

For the long-term survival of a fresh osteochondral allograft there are three prerequisites. The transplanted chondrocytes must remain viable, they must continue to produce sufficient proteoglycan and collagen to maintain the cartilage tissue, and subchondral bone support must be preserved.

Jimenez and Brighton (1983) studied fresh femoral condylar allografts in rabbits and found 56% good or excellent histological grades in the articular cartilage one year after transplantation. Oakeshott et al (1988) examined 18 failed fresh osteochondral grafts and found viable

Table I. Eight complications of allograft repair in 92 knees

Stiffness requiring manipulation	3
Reflex sympathetic dystrophy	1
Wound haematoma	1
Rupture of the patellar tendon	1
Respiratory problems	2

Table II. Revision procedures employed in 13 cases of failed allografts

Total knee arthroplasty	6
Arthrodesis	3
Further allograft	3
Curettage and drilling	1

chondrocytes in 66% of them. Stevenson et al (1989) compared fresh and frozen osteochondral allografts in antigen-matched and antigen-mismatched dogs. They showed that, in the cryopreserved grafts, only 40% to 50% of the chondrocytes survived and that the cartilage became degenerate. By contrast, the chondrocytes in the

fresh allografts remained viable, and cartilage thickness was preserved even when they were injected into antigenically mismatched hosts. Although freezing the allograft diminished the immune response to it, the severe damage sustained by the cartilage outweighed this advantage.

Czitrom, Keating and Gross (1990) were the first to demonstrate live chondrocytes in biopsies of fresh osteochondral allografts obtained from patients one to six years after transplantation. The proportion of viable chondrocytes ranged from 69% to 99% and they were shown to be producing proteoglycan.

Our survivorship study demonstrates that fresh

Fig. 6

Survivorship graphs for unipolar allografts in males and females (2-tailed $p = 1.00$).

Fig. 7

Survivorship graphs for unipolar allografts to the tibia and to the femur (2-tailed $p = 0.74$).

Fig. 8

Survivorship graphs for unipolar allografts on the medial side and on the lateral side of the knee (2-tailed $p = 1.00$).

osteochondral allografts, performed for post-traumatic defects of the knee, give good clinical results in 75% of cases at five years after transplantation and in 63% at 14 years. Bipolar grafts had a lower success rate than unipolar grafts at all time periods. Although this trend was not statistically significant, our present aim is to perform a unipolar graft before secondary changes on the other joint surface necessitate a bipolar graft.

Zukor et al (1989) described the radiographic findings in this same group of patients. They noted that the radiographic joint space was preserved or only slightly reduced in most cases for several years following transplantation.

It seems, then, that human chondrocytes, when implanted as a fresh composite osteochondral allograft, can survive for prolonged periods but that they slowly deteriorate. The cause for this deterioration is unclear but may be related to inadequacy of graft fixation and stability (Jimenez and Brighton 1983), mechanical overloading of the graft (Oakeshott et al 1988), immunological assault by the host synovium (Yablon 1983) or incongruence between the articular surfaces of graft and host (Rodrigo 1983).

The role of the immune response in the incorporation and survival of fresh osteochondral allografts is important. The fact that bone provokes an immune response is undoubted. Langer et al (1975) demonstrated lymphocyte migration following transplantation of fresh osteochon-

Fig. 9

Survivorship graphs for unipolar and bipolar allografts performed in patients less than 60 years and 60 years or older (2-tailed $p = 0.08$).

dral allografts indicating a cell-mediated immune response to allogeneic bone. Despite this, there was no case in our series where complete rejection of the allograft was the cause of its failure. In the failed fresh osteochondral allografts examined by Oakeshott et al (1988), and referred to above, the graft bone was dead but it had been replaced by creeping substitution. Every graft that had been in place for more than 44 months had complete bony substitution. It is likely that the non-progressive subsidence seen in these grafts is due to collapse of the relatively softened allograft bone during the revascularisation phase of creeping substitution. This subsidence is most likely to occur between two and three years after the transplant (McDermott et al 1988). The reason for the delay in revascularisation may be that the immune response delays the incorporation of the bone graft and its subsequent replacement by host bone. This would also explain the poor clinical and radiological results if joint malalignment is not corrected and the graft is therefore overloaded (Oakeshott et al 1988; Zukor et al 1989).

Although isolated chondrocytes in tissue culture are subject to immune assault, as are other cells, it appears that their surrounding matrix protects them from the ingress of immunocompetent cells thereby rendering them immunoprivileged (Langer and Gross 1974). The long-term survival and function of meniscal allografts have not as yet been convincingly demonstrated in humans but we have seen very promising arthroscopic appearances in menisci transplanted in association with fresh osteochondral allografts (Zukor et al 1990). Long-term analysis of retrieved menisci will be invaluable in determining their place in this type of surgery. The role of the menisci in cartilage nutrition and redistribution of joint contact forces is well accepted and it would seem prudent to preserve or replace them as required.

We believe that the success of fresh osteochondral allografts depends more upon biomechanical factors than upon graft rejection. Close attention must be paid to patient selection, correction of joint malalignment and rigid internal fixation of the allograft to the host. Under no circumstance should the height of the graft be used to correct malalignment of the limb. We recommend a minimum graft thickness of 1 cm.

Although there is a 'learning curve', we think that these techniques are within the capability of most surgeons with experience in knee arthroplasty, providing they have access to a modern tissue retrieval service. These procedures are truly conservative since bone and cartilage are restored and minimal host tissue is removed. Indeed, should the cartilage fail in the course of time, future revision surgery is facilitated by the improved bone stock. The potential benefits to patients in their most active and productive years, who would otherwise require prosthetic replacement or arthrodesis, are evident. Progress in the field of cryopreservation may make it possible, eventually, to store bone and cartilage for prolonged periods while maintaining chondrocyte viability

and function, but until that day, fresh osteochondral allografting of major defects in weight-bearing joints will continue to be the only truly biological solution available.

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