We used fresh small-fragment osteochondral allografts to reconstruct post-traumatic osteochondral defects in 126 knees of 123 patients with a mean age of 35 years. At a mean follow-up of 7.5 years (2 to 20), 108 knees were rated as successful (85%) and 18 had failed (15%).

The factors related to failure included age over 50 years (p = 0.008), bipolar defects (p < 0.05), malaligned knees with overstressing of the grafts, and workers’ compensation cases (p < 0.04). Collapse of the graft by more than 3 mm and of the joint space of more than 50% were seen more frequently in radiographs of failed grafts.

Our encouraging clinical results for fresh small-fragment osteochondral allografts show that they are indicated for unipolar post-traumatic osteochondral defects of the knee in young active patients.

The reconstruction of osteochondral defects of the knee in young active patients is a major challenge. Since the first attempts at osteochondral transplantation by Lexer in 1908,1,2 both animal and clinical studies in immunology and transplantation have shown that transplanted fresh cadaver cartilage is viable.3-9 In these small fragments, allograft is replaced by host bone in a homogeneous fashion by creeping substitution.10-12

Since 1972, we have used fresh osteochondral allografts for the reconstruction of joint defects due to injury. We now present our long-term clinical and radiological results along with a survival analysis of the use of such allografts.

PATIENTS AND METHODS

From 1972 to 1992 we reconstructed 126 knees with osteochondral defects after injury in 123 patients using fresh osteochondral allografts. The average age of the patients was 35 years (15 to 64 ± 12). There were 81 men and 42 women. There had been one or more previous operations on 97 knees (Table I).

The sites of the defects were: tibial plateau (55 lateral, 6 medial and two both medial and lateral); femoral condyle (27 medial, 23 lateral); bipolar tibial and femoral (7 lateral compartment, one medial compartment); and patellofemoral (one in the patellar groove of the femur and one in the patella).

All the donors were under 30 years of age; the grafts were procured according to the American Association of Tissue Banks procedures,13 by harvesting the intact knee within 24 hours of death with the capsule intact and storing it in Ringer’s lactate at 4°C. Tissue typing was not performed.

Operative technique. We used a straight midline skin incision and a medial or lateral parapatellar arthrotomy. The defects were cut down to bleeding cancellous bone, sacrificing little or no healthy bone. All grafts were at least 10 mm thick and were fixed to the prepared defects using 3.5 mm or 4.0 mm cancellous screws through the bony part of the grafts.
of the graft. In 47 knees with damaged or previously excised menisci, we left a meniscal allograft attached to the plateau graft and sutured it to the host capsule.

In 68 knees, an osteotomy was added, being designed to unload the compartment receiving the allograft. There were 37 osteotomies of the distal femur and 31 of the proximal tibia, performed when the damaged compartment appeared to be under more than a physiological load as seen on long-film standing radiographs. We measured the biomechanical axis of the limb and corrected any obvious malalignment.

Valgus deformity secondary to an old fracture of the lateral plateau was managed by a distal femoral varus osteotomy with an allograft of the lateral tibial plateau (Fig. 1). Varus deformity secondary to a medial condylar defect was treated by a high tibial valgus osteotomy and an allograft of the medial femoral condyle (Fig. 2).

In most patients the osteotomy and allografting were performed at the same operation with the aim of achieving overcorrection by 2 or 3°. During the operation, check long-film radiographs were used to assess the femorotibial angle. Some patients had had an osteotomy before referral to us, and others had it as a second-stage procedure three to six months after the allograft, usually when both operations involved the same side of the joint. For example, a patient with a varus deformity secondary to an old fracture of the medial plateau had the osteotomy first and the graft later. Of the 68 osteotomies, 44 were performed at the time of grafting and 19 were done after and five before the allograft.

We made routine use of continuous passive motion for 48 to 72 hours after operation, and all patients used ischial bearing braces for one year to protect the knee from full weight-bearing. Patients were allowed to bear weight in the brace when the osteotomy had united.

Clinical assessment. We used a modified Hospital for Special Surgery Knee scoring system (Table II). Data were obtained either by personal examination or by correspond-

![Table II. Modified Hospital for Knee Surgery scoring system](https://example.com/table2)

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table II. Modified Hospital for Knee Surgery scoring system

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ence with the referring orthopaedic surgeon. Thirteen patients were lost to follow-up and four died from causes unrelated to their allografts. Their results at their latest assessment, all at over two years’ follow-up, are reported.

Survival analysis was by the Kaplan-Meier method with 95% confidence limits calculated using Greenwood’s formula for variance. Success was defined as an increase in knee score of at least 10 points or maintenance of a score of 75 or more, with no need for further surgery. The patients who died or were lost to follow-up were censored. We used the log-rank test to evaluate factors that might predict graft failure, including gender, medial versus lateral grafts, meniscal transplant, postoperative complications, bipolar versus unipolar grafts and whether injury was related to workers’ compensation. Fisher’s exact test or the chi-squared test was used to analyse categorical variables. Analysis of covariance, adjusting for the preoperative score, was used to evaluate the effect of age, workers’ compensation status, prior surgery and postoperative complications on the postoperative score.

Radiological assessment. The mechanical alignment was assessed in the 99 knees for which long-film standing radiographs were available before and after surgery. We recorded varus alignment in medial compartment transplants and valgus alignment in lateral transplants as malalignment which was likely to overstress the graft.

Union, fracture or collapse of the graft, and joint-space narrowing were assessed in the 103 patients who had radiographs of adequate quality. Grafts which lost more than 3 mm of osseous height were recorded as showing significant collapse, and the grading of joint-space narrowing is shown in Table III. Patients who had significant graft collapse and/or joint-space narrowing of more than 50% were recorded as having poor radiological results.

RESULTS

Clinical. The average follow-up was 7.5 years (2 to 22). Of the 126 knees, 108 were successful (86%) and 18 were failures. Four of eight bipolar grafts and 14 of 118 unipolar grafts failed (Fig. 3). Survivorship analysis showed 95% graft survival at five years, 71% at ten years and 66% at 20 years (Fig. 4).

Of the 18 failures, one patient had an arthrodesis eight
years after transplantation and eight had a total knee replacement five to 16 years after operation. None required bone grafting at the time of arthroplasty. One patient had a debridement with partial removal of the graft and eight recorded as failures because of a decrease in score retained their grafts. No grafts failed because of problems with the meniscus but we did not include arthroscopic examination in the assessment. A separate study has confirmed viability of grafted menisci at an average follow-up of 4.5 years. Log-rank tests showed statistically significant relationships between failure and workers’ compensation cases (seven of 21 patients, p < 0.039) and those with bipolar grafts (four of eight patients, p < 0.05) (Fig. 3).

In 18 patients over 50 years of age five knees were...

Fig. 6a Fig. 6b
Figure 6a – Preoperative radiograph of the knees of a 33-year-old patient. The right knee shows a post-traumatic osteochondral defect in the lateral tibial plateau and valgus malalignment. Figure 6b – Postoperative radiograph ten years after an osteochondral allograft and distal femoral varus osteotomy. The graft has united and the height of the graft and joint space are well preserved.

Fig. 7a Fig. 7b
Figure 7a – Preoperative radiograph of the knee of a 35-year-old woman with a post-traumatic defect of the medial femoral condyle. Figure 7b – Postoperative radiograph 12 years after an osteochondral allograft to replace the medial femoral condyle and valgus tibial osteotomy. The graft has united and the joint space is well maintained.
failures ($p = 0.008$). Figure 5 shows the age distribution of failed and successful cases. We found no significant effect for location of the graft, gender, meniscal transplant or postoperative complications.

In the successful cases the mean preoperative and postoperative scores were 66 (19 to 94) and 83 (54 to 100), respectively. The factor producing most increase in the score was pain relief, with an average increase of nine points. Adjusting for preoperative scores, analysis of covariance showed that only workers’ compensation had an adverse predictive effect on achieving a low postoperative score ($p < 0.0005$).

**Radiological.** There were adequate pre- and postoperative radiographs for 103 patients. Two showed doubtful union, but otherwise all grafts were solidly united to the host bone by six to 12 months after surgery (Figs 6 and 7). No graft fractures were seen, but 30 showed significant graft collapse or 50% joint-space narrowing or both and were recorded as poor radiological results.

In the clinically failed group 12 of 15 radiographs showed poor results while of the successful cases 18 of 88 radiographs were poor. The difference was statistically significant ($p = 0.00001$) (Fig. 8).

Malalignment was seen in nine of 29 poor radiographs compared with five in 70 good radiographs ($p = 0.003$). In

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**Fig. 8**

Bar graph showing the correlation between clinical outcome and radiological results.

**Fig. 9**

Photomicrographs of a retrieved distal femoral allograft transplanted 12 years earlier for a post-traumatic defect of the distal anterior surface of the femoral side of the patellofemoral articulation. Figure 9A – Photomicrograph of graft cartilage at the surface of the cartilage showing the thickened lamina splendens. There is focal chondrocyte necrosis (arrow) and focal chondrocyte clustering (haematoxylin and eosin ×125). Figure 9B – Photomicrograph of graft cartilage showing multiple viable chondrocytes sharing chondrons (Toluidine Blue ×385). Figure 9C – Electron photomicrograph of a graft chondrocyte within a chondron. The rough endoplasmic reticulum and cell membranes are intact (×7300).
85 well-aligned radiographs (p = 0.0099), 14 showed moderate or severe joint-space narrowing compared with seven of 14 malaligned radiographs (p = 0.0009). Of 85 well-aligned cases eight were clinical failures compared with six of 14 malaligned cases (p = 0.0084). Of 18 patients who had considerable graft collapse half were failures.

DISCUSSION

The use of fresh osteochondral allografts is supported by experimental and clinical evidence of the viability and function of cartilage after transplantation. A review of our first 100 cases showed that the best indication for this procedure was a post-traumatic unipolar defect consisting of bone and cartilage, in patients not considered for osteotomy alone because of the size of the osseous defect (Figs 6 and 7). All these cases were referred by other orthopaedic surgeons who also considered that osteotomy alone was not appropriate, because of loss of cartilage and bone involving at least one-third of the condyle or plateau and at least 5 mm in depth. This loss had caused marked pseudolaxity and biomechanical imbalance, even after a previous osteotomy. In this relatively young group of patients, bone stock and stability were important to delay the need for joint replacement.

We have shown histological viability of chondrocytes in retrieved grafts at 12 years after transplantation (Fig. 9) and chondrocyte function by radioisotope studies at six years. The bony parts of these small grafts are replaced by host bone in two to three years by creeping substitution. Union between the host and graft takes place at about six months and a significant portion of the graft has been replaced at one year although the graft may be subject to collapse for two to three years.12,13 We therefore advise the use of a brace only for one year but suggest that impact activities are avoided for two to three years.

In our series, 14 of our 18 failed cases had adequate long-term standing radiographs. Six showed malalignment likely to overstress the graft, as against only eight of 85 successful cases. Nine of the 29 patients with poor radiological results had malalignment compared with only five of 70 with good radiological results. Our study therefore shows a clear correlation between good alignment and good clinical and radiological results. Previous reports have shown little correlation between radiological changes and clinical failures,14 but we found a highly statistically significant relationship (p = 0.00001) in our study. Our survivorship analysis has shown satisfactory results in 95% after five and in 77% after ten years. We have previously emphasised the importance of patient selection and confirmed that young compliant patients with unipolar traumatic defects obtain the best results.23-25

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

REFERENCES