CHAPTER 5

Osteochondral allografts for articular defects of the knee

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Summary

The use of osteochondral allografts provides a reconstructive solution for treating young, active patients with large osteoarticular defects of the knee. Osteochondral allografts are useful where implants or an arthrodesis are not desirable. Although the use of allografts has a risk of disease transmission similar to blood transfusion, there are significant advantages since there is no donor site morbidity, the bone stock can be restored and the allografts can be adjusted in size and shape to fit the defect exactly. There is an 85% long-term survival rate of osteochondral allografts in carefully selected patients, who present with osteochondritis dissecans or traumatic defects of the knee. This chapter discusses the indications and contraindications of osteochondral allografts, outlines the peri-operative management of patients and reviews the long-term results presented in the literature.

KEYWORDS: Osteochondral allografts, Articular cartilage, Knee injuries, Transplantation, osteotomy

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INTRODUCTION

A chondral injury on a weight bearing area of the knee may lead to the development of osteoarthritis and deterioration in knee function (1-6). Articular cartilage has no inherent regenerative capability and full thickness cartilage lesions do not heal. From the various types of cartilage, hyaline cartilage has superior biomechanical properties and is more durable (7-9). Fibrocartilage repair tissue not only has inferior mechanical properties but also degenerates with loading over time (10). There is a growing interest in the treatment of these lesions, because of their poor functional outcome and also because they are increasingly more common in the younger population (11). Osteoarticular autograft transplantation, osteoarticular allograft and autologous chondrocyte implantation can help in the repair of hyaline cartilage (5).

FRESH CADAVERIC ALLOGRAFT

The use of fresh osteochondral allografts for the treatment of osteochondral defects of the knee is based on a scientific rationale and on long-term clinical experience. Fresh avascular osteochondral allografts, if harvested within 24 hours of death and preserved at 4˚C show 100% viability of cartilage at four days (12-14). Although, freezing decreases the immunogenicity of the bone to some degree, it also results in decreased chondrocyte viability (15,16). Even cryopreservation and controlled rates of freezing and thawing will not achieve an acceptable degree of cartilage viability (15). The matrix that surrounds chondrocytes isolates them from the host's immune cells and prevents host sensitization (17). The avascular bone remains structurally intact and mechanically strong until it is replaced by host bone by creeping substitution (18). Although the osteocytes will not survive unless the graft is vascularised, the use of immunosuppressive drugs to counter the increase in immunogenicity, cannot be justified in this setting. In a series of failed fresh osteoarticular allografts between 12 and 84 months after transplantation, none has demonstrated histological evidence of transplant rejection (19). Long-term chondrocyte viability of fresh osteochondral allografts has been confirmed in a number of studies, even at 17 years after transplantation (18,20-22).

The use of osteochondral allografts represents a reconstructive solution for treating young, high-demand patients where implants or arthrodesis are not desirable (23,24). Allografts have the advantage of providing flexibility in terms of the size of defect that can be used for. Both femoral and tibial defects can be addressed and where needed, the allograft meniscus can

also be transplanted (23). Appropriate patient selection is paramount to satisfactory outcome. A number of patient characteristics have been identified that are predictive of success of the procedure.

INDICATIONS AND CONTRAINDICATIONS

Indications for the use of fresh osteochondral allografts are steroid-induced avascular necrosis of the femoral condyle, osteochondritis dissecans and, most commonly traumatic defects of the knee (25). At the authors' institution, the use of allografts is considered as a surgical option for treating osteochondral defects of greater than 30mm diameter and 10mm deep (26).

Diagnosis

McDermott *et al*. (25) reviewed the first 100 patients who received fresh, small-fragment osteochondral allografts for the treatment of articular defects of the knee. Initially, the grafts were used in cases of unicompartmental osteoarthritis, spontaneous osteonecrosis of the knee, steroid-induced avascular necrosis of the femoral condyle, osteochondritis dissecans, and most commonly, traumatic defects of the knee. Grafts used in the treatment of trauma cases were reported to have the best results. Those used for treating degenerative joint disease had the worst results (27,28). Meyers *et al.* also showed poor results when fresh allografts were sued in treating osteoarthritic knees (28). Garrett (29) produced excellent mid-term results for patients with osteochondritis dissecans. Most authors agree that posttraumatic defects and osteochondritis dissecans of the knee are the best indications for fresh grafting (18,23,25,27-32).

In our experience, the best results obtained with treating fresh osteochondral allografts were in patients with unicompartmental posttraumatic defects and osteochondritis dissecans of the knee. At the authors' institution osteochondral allografts are no longer used for treating osteoarthritis, spontaneous osteonecrosis, or steroid induced osteonecrosis, or in patients with inflammatory arthropathy. If a posttraumatic defect has been present for a long time and severe degenerative changes are seen in the opposing articular surface, an allograft is contraindicated.

Age

Beaver *et al*. (33), used Kaplan-Meier survivorship analysis, to demonstrate that patients younger than 60 years of age with posttraumatic defects had better results with the use of osteochondral allografts than older patients had. Fortunately, most post-trauma patients are in their twenties and thirties.

Site

The use of allografts for treating bipolar lesions of the knee (femur and tibia) has not been reported to be as successful as the ones used in treating unipolar lesions (18,23,25,31-33). Patients, therefore, should be referred for surgery before secondary changes occur on the nontraumatized side of the lesion.

Size

Recent advances in other techniques for cartilage repair and resurfacing, such as the use of microfracture technique, autologous chondrocyte implantation, osteochondral autografts, and periosteal grafts (34-39), have reduced the role of allograft transplantation to defects larger than 30mm in diameter and 10mm deep (26).

Deformity

Most osteoarticular defects have a concomitant malalignment of the lower limb. In order to unload the compartment that has received the transplant, any malalignment should be addressed with a realignment osteotomy of the tibia or femur, as appropriate (40,41). If indicated, the osteotomy should be performed at the same time as the osteochondral allograft transplantation. Delayed osteotomy should be reserved as a salvage procedure for a deteriorating graft when the mechanical axis passes through the grafted compartment, and only in very young patients (26).

ADVANTAGES AND DISADVANTAGES

Several advantages to the use of cadaveric allografts exist. There is no donor site morbidity and the osteochondral defect can be addressed exactly in terms of size and contour. However, the use of fresh osteochondral allografts has some disadvantages. An organized transplant service is

required, procedures cannot be carried out on an elective basis and there is a risk of disease transmission similar to that of homologous blood transfusion (HIV 1:493,000, Hepatitis C 1:103,000 and Hepatitis B 1:63,000) (42,43), although there are some published estimates of lower risk (44).

PREOPERATIVE PLANNING

Preoperative assessment should include a clinical and radiological evaluation of the injured knee. The presence of previous scars or metalware that may need to be removed, might determine the placement of the skin incision. Routine radiographic views of the knee and a 3-foot standing radiograph provide data necessary to estimate the location, size, and shape of the defect and required graft. Careful assessment for the presence of degenerative changes and the need to correct alignment must be done. The biomechanical axis is used to evaluate any deformity and plan correction. In some patients, previous arthroscopic surgery reports might help evaluate the size of the defect, secondary degenerative changes, and status of the opposing surface cartilage.

GRAFT PROCUREMENT AND HANDLING

The local organ procurement agency (e.g. The Trillium Gift of Life Network - Ontario's Organ and Tissue Donation Agency) identifies potential donors. The donor must meet the criteria outlined by the American Association of Tissue Banks (45). The donors must be less than 30 years old to provide healthy, viable cartilage and strong bone. Graft procurement is carried out within 24 hours of death, under strict aseptic conditions with the specimen consisting of the entire joint with the capsule intact. Before harvesting, standardized radiographs of the knee are obtained, and the recipient is matched to the donor with regard to size (height and weight). Cultures (aerobic, anaerobic, fungal and tuberculosis) and blood for serology are taken, but no tissue typing or HLA matching is required. The graft must be stored in a sealed sterile container in sterile Ringer's lactate at 4^{o}C with cefazolin (1g) and bacitracin (50,000U) per liter of solution. The recipient patient is notified as soon as a donor has been located and is admitted to the hospital as prearranged. Implantation is performed within 48 hours of the harvest (graft procurement), but we are willing to extend it to 96 hours based on previous research (13,14,46,47).

SURGERY

Two surgical teams can work simultaneously. One team performs the arthrotomy on the recipient patient, while the other prepares the allograft. The graft is prepared on a separate table with a separate set of instruments. At the time of soft-tissue removal, care must be taken to preserve the donor menisci and the articular cartilage. The osteochondral fragment is gradually shaped to fit the defect. It is kept in Ringer's lactate and antibiotic solution until implantation.

The patient lies supine on a radiolucent table. One gram of cefazolin antibiotic is given intravenously to the patient at the induction of anaesthesia. The leg is prepared and draped to allow an extensile anterior approach to the knee, the old scars are marked, and the tourniquet is inflated. It is important after draping to have access to the anterior superior iliac spine by palpation and the ankle to evaluate alignment.

The surgical approach

A straight mid-line incision is performed. This allows access to the defect site as well as permitting a proximal tibia or distal femoral osteotomy, if one is required. The same midline incision can be used for any future procedures, thus preserving the skin flap blood supply. If the knee has previous incisions, an alternative approach may be needed to avoid potential skin necrosis. The incision is approximately 250 to 350mm long and is centered over the patella. Proximally, it overlies the quadriceps tendon and distally, it overlies the tibial tubercle. A medial or lateral parapatellar arthrotomy is made, depending on the site of the defect. Where varus deformity exists, the authors prefer to perform a medial opening wedge tibial osteotomy. There is usually no difficulty in performing a standard high tibial osteotomy through this approach. If a distal varus femoral osteotomy is required, the medial aspect of the distal femur can be approached through a midline skin incision and a subvastus approach.

Preparation of the recipient bed and grafting

Once the joint is exposed, the reconstruction is straight forward and quite conservative. The articular defect is "squared off" with the goal of removing as little bone as possible. The resection is down to bleeding cancellous bone. Precise measurements are done and the graft is machined to fit the recipient bed accurately. The graft is orthotopic and the graft's articular

surface has to lie flush with that of the host joint. Femoral allografts are usually inserted with a press fit technique, whereas tibial allografts are usually fixed in place with two or three 4.0mm partially threaded cancellous screws (48). Enough bone must remain on the allograft to accommodate screw fixation (at least 1cm).

Realignment

According to the preoperative planning a realignment procedure should be carried out.

High tibial osteotomy (medial opening wedge)

If varus deformity exists a lateral-closing-wedge high tibial osteotomy can be performed with a medial femoral condyle allograft for realignment in valgus (41). Lately, the senior author has used a medial-opening-wedge high tibial osteotomy and fixation with a Puddu plate for valgus realignment (49). The characteristic of this plate is that is has a spacer that fits into the osteotomy site. Calculating the degrees of correction determines the width of spacer used. It is important to aim for overcorrection from physiological valgus in order that the post correction mechanical axis of the lower limb passes 3-4mm into the lateral tibiofemoral compartment.

Distal femoral varus osteotomy

The distal femoral varus osteotomy that is performed concurrently with a lateral tibial plateau graft is a closing wedge medial osteotomy (40).

Surgical Pitfalls

Tibial graft fixation

When the graft is fixed to the recipient site with screws, we drill the first hole with a 2.5mm drill bit and leave it in place while drilling the second hole. After insertion of a screw into the second hole, the first drill bit is removed and replaced by a screw. This sequence provides good stabilization of the small allograft fragment while drilling holes for the screws. One needs to make sure that the screws do not interfere with other metalwork, do not protrude into soft tissues, and are not too close to the articular surface.

Realignment procedure

The allograft itself should not be used to correct limb alignment. This is usually achieved via an osteotomy. When a realignment procedure is done at the same time as transplantation, it should be carried out after allograft fixation. If the realignment procedure involves the same side of the joint as the graft, it should be carried out several months before transplantation to allow sufficient time for revascularization of host bone.

POSTOPERATIVE MANAGEMENT

Grafted limb is placed in an above knee cylindrical fiberglass cast for two weeks post-surgery. At two weeks a hinged knee brace is used and physiotherapy is started. Active and active-assisted range of movement exercises, isometric strengthening exercises and non-weight bearing ambulation with crutches is continued for three months. No resisted exercises are performed until there is radiographic evidence that the osteotomy is healed.

RESULTS

The use of fresh osteochondral cadaveric allografts for treating osteochondral defects of the knee has encouraging mid- to long-term results (31,50-53). In a recent report, survival of fresh femoral allografts was reported to be 74% at 15 years with 61% of patients achieving excellent or good functional outcomes. These outcome included the development of degenerative joint disease as a mode of failure (26). Agnidis *et al* compared the SF-36 scores of 47 patients with transplants for large articular defects to normative date from an age-matched group. At an average of 12 years follow-up, the patients with transplants had favorable results in every category, and 93% considered the operation successful (54).

In an earlier study performed at the authors' institution (51), 126 knees of 123 patients with osteochondral defects secondary to trauma (111 cases) or osteochondritis dissecans (15 cases) were reviewed. The average age at operation was 35 years (range, 15 to 64). There were 81 males and 42 females. The defects were located in the tibial plateau (55 lateral, 6 medial, and 2 combined medial and lateral), femoral condyle (27 medial and 23 lateral), bipolar tibial and femoral (7 lateral and 1 medial compartment) and patellofemoral (1 in patellar groove of the femur and 1 in the patella). The grafts, which were between 8 and 40mm thick, were fixed to bleeding cancellous bone after resecting the defect. In 47 cases the meniscus was included in the

transplant. Sixty-eight knees underwent osteotomy to correct alignment (37 distal femoral, 31 proximal tibial). Patients were assessed clinically pre- and post-operatively, using a rating score based on subjective and objective criteria. Radiographic assessment included alignment, graft union, fracture and resorption, joint-space narrowing and osteoarthritis. The average follow-up was 7.5 years (range, 1 to 22). Failure was defined as a decrease in knee score or the need for further surgery. Kaplan-Meier survivorship analysis demonstrated 95% successful results at five years (95% confidence limits: 87 to 98), 71% at 10 years (95% confidence limits: 56 to 83), and 66% at 20 years (95% confidence limit: 50 to 81). Among 18 failures, one patient had an arthrodesis, eight had total knee replacement, one had removal of the graft, and eight experienced failure because of a decrease in score but still retain these grafts. The success rate was 85%.

COMPLICATIONS

In the above prospective cohort study, five complications were noted. These included three stiff knees, one wound haematoma, and one rupture of the patellar tendon. Long-term analysis showed a statistically significant relationship for failure with bipolar grafts ($p<0.05$) and patients receiving worker's compensation ($p=0.0396$). There is no statistically significant relationship with other factors such as osteotomy, meniscal transplant and medial or lateral side of the knee. Additionally, analysis of variance in successful cases did not show any statistically significant effect on patient age or sex, postoperative complications, or preoperative scores. Radiographic assessment of 18 patients with failed procedures showed four collapsed grafts, seven patients with loss of joint space, and 10 with significant osteoarthritis.

Except for two instances of delayed union, all grafts were solidly united to the host bone 6 to 12 months post surgery. Among clinically successful patients, we noted five instances of mild graft collapse (less than 3mm), 11 of decreased joint space, and 18 of osteoarthritic changes. Although most patients experiencing failure showed radiographic changes, similar changes were seen in some patients in whom the procedure was successful.

In a functional outcome study, the SF-36 scores of 47 patients with successful transplants were compared to normative data from an age-matched group (54). The greatest discrepancies in the SF-36 scores were in the categories of physical functioning and "role physical". Despite this, patients returned to a normal life-style, including leisure sports but not competitive sports.

A recent study looked at 60 patients who were a minimum of five years (average, 10 years) from the time of transplantation of fresh osteochondral allografts of the femoral condyles (52). Excellent long-term survival is demonstrated, with 85% (confidence limits, 41% to 100%) of cases surviving without further surgery at 10 years, and a projected survivorship of 74% at 15 years. In the 12 patients with more than 15 years follow-up, only four have failed. Equally important is the mean 10-year Hospital for Special Surgery (HSS) score of 83, with 84% of patients reporting good to excellent overall outcomes. The mean score for pain was 28 (mild pain requiring occasional analgesics), and most patients were able to walk more than one mile with few problems.

CONCLUSIONS

Overall, the high success rate in mid- to long-term follow-up of using ostechondral allografts, makes it a good procedure for treating unipolar osteochondral defects of the knee, in properly selected patients, post trauma or osteochondritis dissecans. Ostechondral allografts do not compromise salvage surgery and can help to restore bone stock.

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