

OSTEOCHONDRAL ALLOGRAFT TRANSPLANTATION

CLINICAL OUTCOME AND RETURN TO SPORT

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Articular cartilage transplantation, in the form of fresh osteochondral allografting, has emerged as one of the most important techniques for restoration of articular cartilage in North America^{1,2}. Osteochondral allografts (OCA) repair articular cartilage defects by restoring mature, living, hyaline cartilage in a biologically, structurally and functionally appropriate manner. Fresh OCA transplantation has been used to treat of a wide spectrum of knee articular pathology related to injury or resultant from joint disease. OCA transplantation has emerged as an important and versatile option in the restoration of articular cartilage, particularly for lesions with both an osseous and a chondral component, such as those seen

with osteochondritis dissecans. Furthermore OCA transplantation is increasingly used as a salvage procedure when other cartilage repair procedures such as microfracture, autologous chondrocyte implantation or osteochondral autograft transfer have failed.

We have studied osteochondral allografting both in the clinic and the laboratory for more than 30 years³ and have come to understand a number of principles. The fundamental concept governing fresh osteochondral allografting is the transplantation of architecturally-mature hyaline cartilage, with living chondrocytes that survive transplantation and are thus capable of supporting the cartilage matrix.

Hyaline cartilage possesses characteristics that make it attractive for transplantation. It is an avascular tissue and therefore does not require a blood supply, meeting its metabolic needs through diffusion from synovial fluid. It is an aneural structure and does not require innervation for function. Thirdly, articular cartilage is relatively immunoprivileged, as the chondrocytes are imbedded within a matrix and are relatively protected from host immune surveillance.

The second component of the osteochondral allograft is the osseous portion. This generally functions as a support for the articular cartilage, as well as a vehicle to allow attachment and fixation of the graft to the host. The osseous portion of

SUMMARY: GOVERNING PRINCIPLES FOR OSTEOCHONDRAL ALLOGRAFTING

- *Whole tissue or organ transplant.*
- *Viable chondrocytes.*
- *Mature hyaline cartilage matrix.*
- *Chondrocytes survive transplantation and maintain matrix.*
- *Cells within matrix are immunoprivileged.*
- *Osseous portion is a non-living osteoconductive scaffold.*
- *Interface for attachment and integration.*
- *Transplant minimal bone volume necessary for restoration or fixation.*
- *Graft incorporates by creeping substitution.*
- *Potential site for immunologic response.*
- *Behaviour of osseous component is most important factor in clinical outcome.*



Figure 1: Type 4 osteochondritis dissecans lesion of the medial femoral condyle resulting in large osteochondral lesion.

the graft is quite different from the hyaline portion, as it is a vascularised tissue — cells are not thought to survive transplantation; rather, the osseous structure functions as a scaffold for healing to the host by creeping substitution (similar to other types of bone graft). Generally, the osseous portion of the graft is limited to a few millimeters. It is helpful to consider a fresh osteochondral allograft as a composite graft of both bone and cartilage, with a living mature hyaline cartilage portion and a non-living subchondral bone portion.

It is also helpful to understand the allografting procedure in the context of tissue or organ transplantation, as the graft is essentially transplanted as an intact structural and functional unit replacing a diseased or absent component in the recipient joint. The transplantation of mature hyaline cartilage obviates the need to rely on techniques that induce cells to form cartilage tissue, which are central to other restorative procedures.

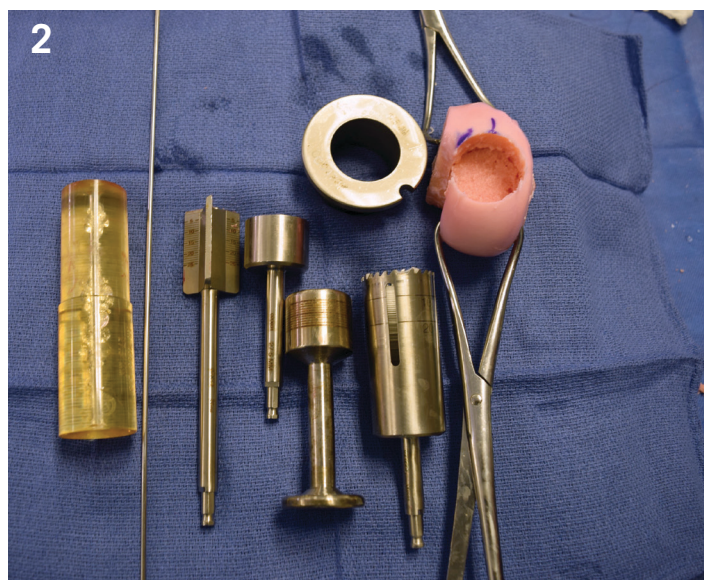
The cornerstone of an allografting procedure is the availability of fresh osteochondral tissue. Currently small-fragment osteochondral allografts are not human leukocyte antigen- or blood type-matched and are used fresh, rather than frozen or processed. The rationale for

fresh tissue is predicated on the concept of maximising the quality of the articular cartilage in the graft. It has been shown, primarily through retrieval studies that viable chondrocytes and relatively preserved cartilage matrix are present many years after transplantation. These experiences have supported the use of fresh instead of frozen tissue, which shows more rapid deterioration in both animal and clinical studies³. Understanding the process of tissue procurement, testing and storage is critically important in the allografting procedure. Historically, the obstacles presented led to the development of fresh allograft transplant programmes only at specialised centres in North America that have a close association with an experienced tissue bank and have put significant investment of resources into setting up specific protocols for safe and effective transplantation of fresh osteochondral tissue. Fresh osteochondral grafts have been commercially available in North America since 2002, thanks to advances in tissue banking and viable tissue storage protocols. Interest in the technique has led to the development of technologies (donor programmes, tissue banking, legislation, clinical logistics) to allow for programmes to be developed around the world.

Indications for fresh osteochondral allografts¹

Conditions of the knee indicated for treatment with fresh OCA include large chondral and osteochondral lesions, osteochondritis dissecans (Figure 1), focal avascular necrosis and other conditions involving cartilage disease or absence of subchondral bone such as fracture malunion. Increasingly, fresh OCA is used in the setting where other cartilage repair procedures such as microfracture, osteochondral autologous transfer or autologous chondrocyte implantation have failed. In select cases where arthroplasty is relatively contraindicated, fresh OCA can be used to treat degenerative knee conditions.

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INDICATIONS FOR OSTEOCHONDRAL ALLOGRAFTS

- *Revise previous cartilage surgery*
- *Traumatic or degenerative chondral lesions*
- *Osteochondritis dissecans*
- *Post-traumatic reconstruction*
- *Osteonecrosis*
- *Salvage OA situations*
- *Cartilage repair algorithms: lesions >2 cm²*



Figure 2: Typical surgical instruments to harvest a large plug of dowel-type allograft. Note donor allograft in upper right. A 25 mm graft has been harvested.

Figure 3: Recipient site and allograft after preparation.

Figure 4: Reconstructed medial femoral condyle with allograft inserted.

Surgical technique

The surgical technique for fresh osteochondral allografting depends on the joint and surface to be grafted. Common to all fresh allografting procedures is size-matching the donor with the recipient. An anteroposterior radiograph with a magnification marker is used and a measurement of the medial-lateral dimension of the tibia or femoral condyle is made and corrected for magnification. Some surgeons may prefer to use measurements based on MR or CT images, the tissue bank makes a direct measurement on the donor

tibial plateau or femoral condyle. A match is usually considered acceptable at ± 2 mm.

Decision-making for plug or shell technique

The two commonly-used techniques for the preparation and implantation of osteochondral allografts include the press fit plug technique and the shell graft technique. Each technique has advantages and disadvantages. The press fit plug technique is similar in principle to autologous osteochondral transfer. A number of commercially available instruments are available (Figure 2). This technique is optimal

for contained condylar lesions between 15 and 30 millimeters in diameter (Figure 3). Fixation is generally not required due to the stability achieved with the press fit (Figure 4). Disadvantages include the fact that very posterior femoral condyle and tibial plateau lesions are not conducive to the use of a circular coring system and may be more amenable to shell allografts. Additionally, the more ovoid or elongated a lesion is in shape, the more normal cartilage needs to be sacrificed at the recipient site in order to accommodate the circular donor plug. In these cases we often 'stack' two or more



SURGICAL PROCEDURE SUMMARY⁴

smaller plugs. Shell grafts are technically more difficult to perform and typically require fixation but are ideal for resurfacing the tibial plateau or patella.

Postoperative rehabilitation

Initial postoperative management includes attention to control of pain, swelling and restoration of limb control and range of motion. Patients are generally limited to 25% weight bearing for 4 to 6 weeks, depending on the size of the graft and stability of fixation. Patients with patellofemoral grafts are allowed weight bearing as tolerated in extension and are limited to 45 degrees of flexion for the first 4 weeks, using an immobiliser or range-of-motion brace. Closed-chain exercise such as cycling is introduced between weeks 2 and 4.

Weight bearing is progressed as tolerated between the 2nd and 4th month. Full weight bearing and normal gait pattern are generally tolerated between the 2nd and 4th month. Recreation and sports are not reintroduced until joint rehabilitation is complete and radiographic healing has been shown, which generally occurs no earlier than 3 to 6 months postoperatively.

One true advantage of OCA over other cartilage repair procedures is a much more rapid recovery and return to weight bearing and regular activity. This is because the graft only requires stability and bony healing and not growth of 'new' cartilage. This concept and our experience that grafts heal readily has led us to experiment with an immediate unrestricted weight bearing protocol.

Clinical outcome

We have performed over 900 fresh OCA procedures and have clinical outcome data extending 25 years (Figure 5). More recently, other authors have reported on their experience with OCA transplantation. Overall, clinical follow-up studies have generally shown success rates between 70 and 95%^{4,5}, with survivorship depending on diagnosis, patient age, graft size and anatomic location (Figure 6).

Return to sports

Although OCA is now an integral part of the cartilage repair paradigm, there is little specific data on return to athletic activity after this procedure.

- *Currently available instruments can create grafts between 10 and 35 mm in diameter.*
- *Osteochondral allografting is performed through a mini or standard arthrotomy.*
- *The defect is exposed and sized and a guide pin placed through the centre of the lesion, perpendicular to the joint surface.*
- *The lesion is reamed to a modest depth removing diseased cartilage and a small (3 to 6 mm) amount of bone.*
- *Depth measurements are taken from the prepared recipient site.*
- *The allograft plug is removed from the donor tissue using a coring reamer.*
- *Recipient depth measurements are marked on the plug and excess bone removed, creating an osteochondral graft matching the size and depth of the prepared recipient site.*
- *The graft is lavaged to remove blood and debris, bony edges trimmed to facilitate insertion.*
- *The graft is gently inserted with a tamp or with joint compression during range of motion.*
- *Loose grafts are fixed with absorbable pins or screws.*

Traditionally, allografts have been used as a salvage treatment or for complex joint pathology, when other attempts at repair have failed or are inadequate. This potentially skews the patient population to a more chronically disabled and less active group with less inclination towards high-level sports participation.

The author's experience with OCA of the knee suggests that return to sport is not

dependent on the treatment but rather on the patient's preoperative characteristics (Figure 7). We have collected International Knee Documentation Committee functional scores on all patients and asked sport-specific questions. In summary, younger patients (generally those under 30) and those diagnosed with osteochondritis dissecans routinely return to their chosen athletic activity after OCA. This is

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particularly true for high school athletes. Participation in competitive college sports is not a universal goal of the high school athlete, which confounds the analysis of whether the treatment or other psychosocial issues are important. There is also little data on the use of OCA and return to sport in the professional athlete.

Theoretically return to sport can be achieved relatively rapidly due to the requirement for bone healing, which can occur relatively quickly (3 to 6 months), unlike the tissue differentiation required by other treatments such as microfracture or ACI which takes 6 to 18 months.

One published paper addresses return to athletic activity after OCA. Krych⁶ evaluated 43 patients with an average age of 32.9 years who regularly participated in sports prior to cartilage injury (74% recreational, 23% collegiate, 2% professional) with an average follow-up of 2.5 years after the procedure. Thirty-eight of 43 (88%) had at least limited return to sport while 34 of 43 (79%) achieved full return to sport at preinjury level at an average of 9 months postoperative. Age greater than 25 years and preoperative

FIGURE 5				
Diagnosis	OCA failure	Mean IKDC pain	Mean IKDC function	Satisfaction
Traumatic chondral injury	2%	3.3	7.3	90%
Osteochondritis dissecans	7%	2.1	8.1	96%
Fracture	15%	4.4	6.1	80%
Degenerative chondral lesion	21%	3.7	6.3	81%
Avascular necrosis	25%	2.7	7.1	92%
Osteoarthritis	29%	3.5	5.8	79%

Figure 5: Summary of clinical outcome of OCA in the author's series. IKDC=International Knee Documentation Committee.

symptom duration greater than 12 months were negative predictive factors for return to sport.

We recently performed a review of our experience with athletic individuals undergoing OCA in the knee (Figure 8). At a mean follow-up of 6 years, 76% (113 of 149) returned to sport or recreational activity. Among the 113, 28% returned to the same

level of pre-injury sport, 48% partially returned (returned to one or more but not all of the same sports or activities) and 25% returned to a different sport or activity. Among the 24% (36 of 149) who did not return to sport or activity, reasons included lifestyle events such as starting a family, changing careers, end of organised sports, knee-related issues and worry about re-

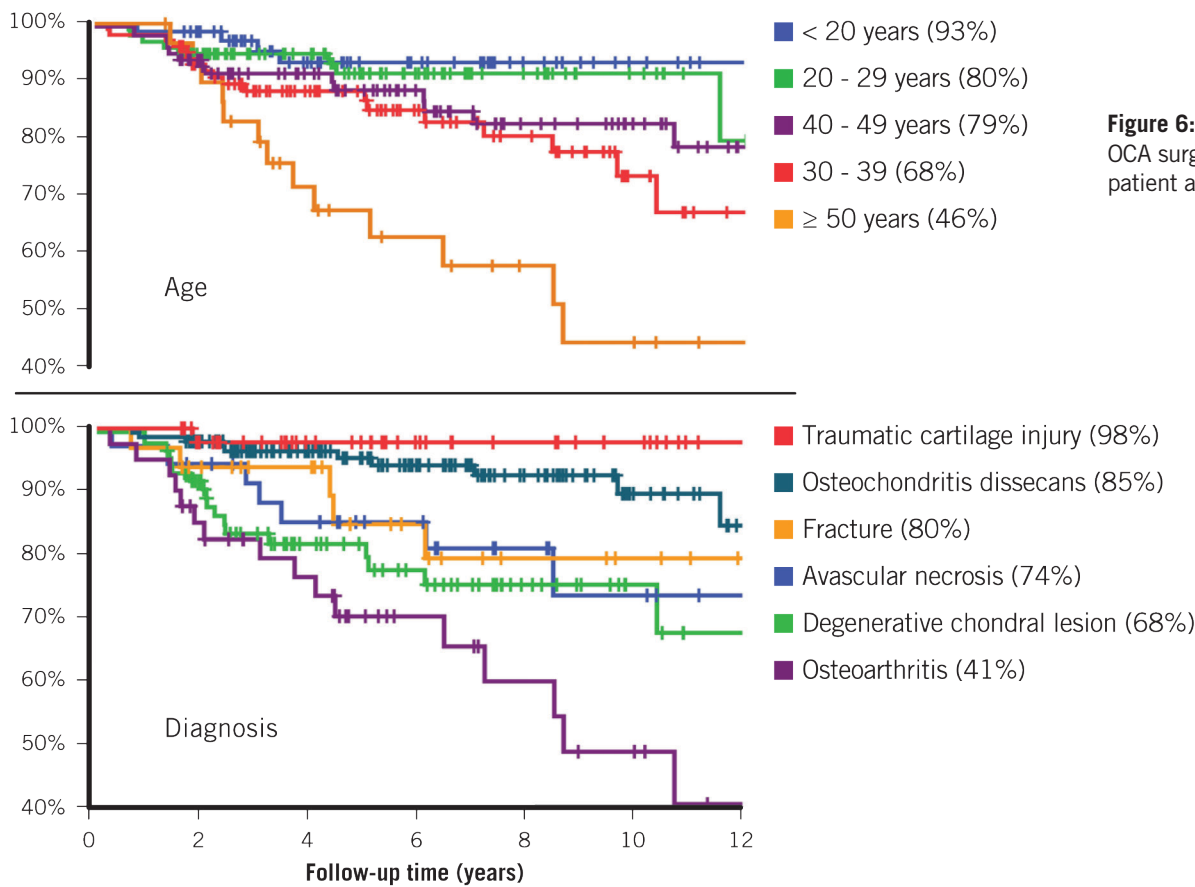


Figure 6: Survivorship of OCA surgery based on patient age and diagnosis.

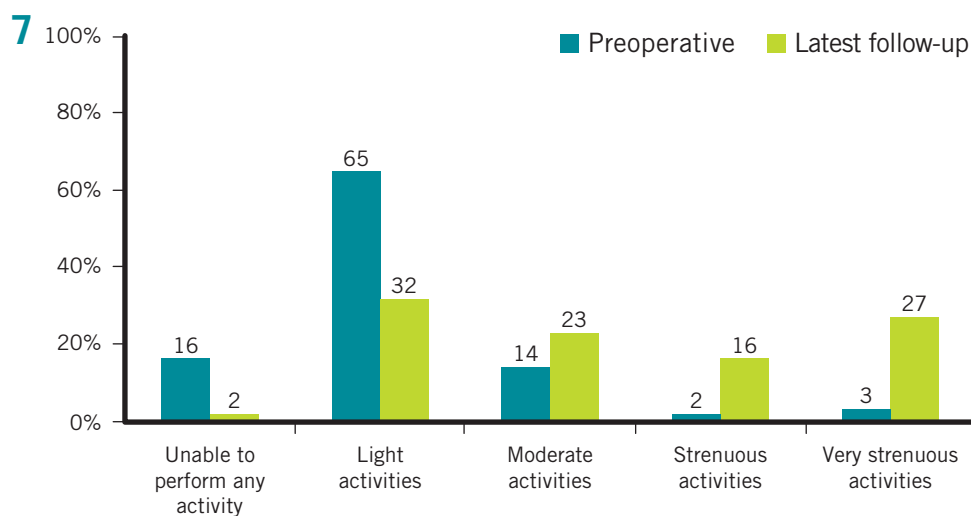


Figure 7: Self-reported IKDC functional improvement after OCA surgery. IKDC=International Knee Documentation Committee.

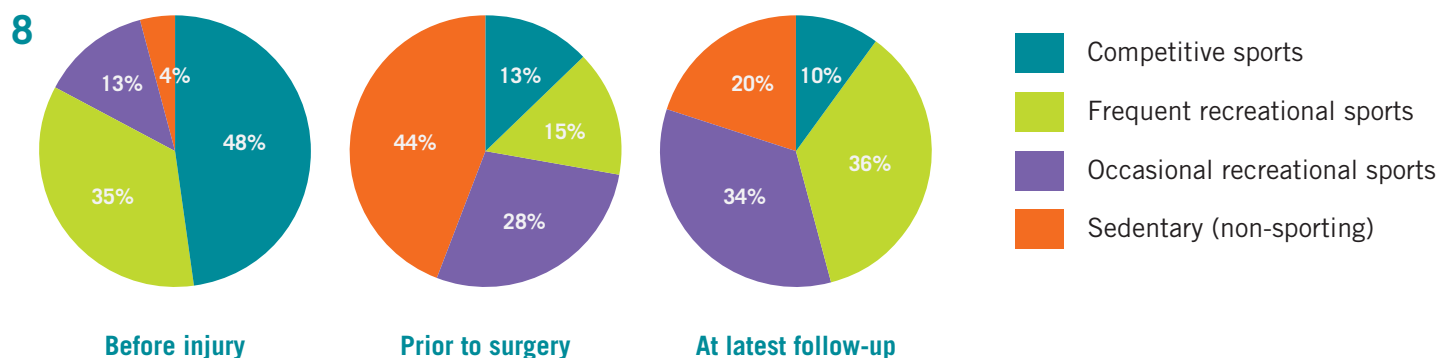


Figure 8: Rates of return to sport after OCA surgery.

injuring the knee. Postoperatively, 79% were able to participate in high-level activity (moderate, strenuous or very strenuous activities) and 71% reported having 'very good' to 'excellent' function. Patients who did not return to sport following OCA were more likely to be female, have injured their knee in an activity other than sports and had a larger graft size. The increasingly mainstream use of OCA (particularly in North America) demands that we develop more data on activity levels after surgical intervention. A number of investigators are pursuing this question. For now, clinical experience suggests that the rate of return to sport is similar to other cartilage repair interventions and that patient characteristics such as age, symptom duration, overall joint status and intensity and type of sport participation are more important variables than the OCA procedure itself.

SUMMARY

Fresh osteochondral allograft transplantation has become a popular and effective treatment for individuals with

difficult cartilage injuries, particularly in the knee. Success is predicated on a sound understanding of the principles, technical aspects and patient selection. A high rate of patient satisfaction and return of function can be expected.

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