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Fresh Osteochondral Allografting in the Treatment of Osteochondritis Dissecans of the Femoral Condyle

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Background: The treatment of osteochondritis dissecans in the adult knee can be challenging. As part of our comprehensive treatment program, fresh osteochondral allografts have been used in the surgical management of osteochondritis dissecans of the femoral condyle.

Hypothesis: Fresh osteochondral allograft transplantation will provide a successful surgical treatment for osteochondritis dissecans of the femoral condyle.

Study Design: Case series; Level of evidence, 4.

Methods: Sixty-six knees in 64 patients underwent fresh osteochondral allografting for the treatment of osteochondritis dissecans. Each patient was evaluated both preoperatively and postoperatively using an 18-point modified D'Aubigné and Postel scale. Subjective assessment was performed using a patient questionnaire. Radiographs were evaluated preoperatively and postoperatively.

Results: Mean follow-up was 7.7 years (range, 2-22 years). There were 45 men and 19 women with a mean age of 28.6 years (range, 15-54 years). All patients had undergone previous surgery. Forty-one lesions involved the medial femoral condyle, and 25 involved the lateral femoral condyle. All were osteochondritis dissecans type 3 or 4. The mean allograft size was 7.5 cm^2. One knee was lost to follow-up. Of the remaining 65 knees, 47 (72%) were rated good/excellent, 7 (11%) were rated fair, and 1 (2%) was rated poor. Ten patients (15%) underwent reoperation. The mean clinical score improved from 13.0 preoperatively to 16.4 postoperatively ($P < .01$). Fifty-nine of 64 patients completed questionnaires. Subjective knee function improved from a mean of 3.4 to 8.4 on a 10-point scale ($P < .01$).

Conclusion: With greater than 70% good or excellent results, fresh osteochondral allograft transplantation is a successful surgical treatment for osteochondritis dissecans of the femoral condyle.

Keywords: osteochondritis dissecans; osteochondral defect; fresh osteochondral allograft; osteochondral transplantation; knee; cartilage

Articular cartilage disease can eventually lead to debilitating injury because of the body's inability to repair this important tissue. Treatment of such articular defects can be challenging in younger patients because of the limitations in management options.

Osteochondritis dissecans (OCD) is one such disease that can damage the joint surface of the knee. Osteochondritis dissecans is a pathologic process in which a fragment of subchondral bone becomes avascular and can separate from the surrounding tissue. Although most lesions are thought to have a traumatic origin, other possible causes include defects of ossification, repetitive mechanical stress, and ischemia.[28,36] The lesion may heal spontaneously, or it may completely separate, become displaced in the joint cavity, and form an intra-articular loose body.[29,36] The resultant lesion in the articular surface does

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not heal, and, if left untreated, the ensuing defect can result in pain, dysfunction, and progress to arthritis while the patient is still quite young.[12,29,33,36] The typical adult patient with OCD is a male in his 20s, and the most common location for the osteochondral defect is the lateral aspect of the medial femoral condyle.[19,28,36]

Surgical treatment for large, full-thickness defects includes loose-body fixation, debridement, microfracture, autologous osteochondral transfer, autologous chondrocyte implantation, allografting, and prosthetic resurfacing.[3,5,6,12,27,38] Fresh osteochondral allografting has been used to treat OCD at our institution for more than 20 years, both as a salvage procedure and as a primary treatment when the fragment could not be reinserted. In this article, we report on the outcomes of allografts in the femoral condyles of 66 knees for the treatment of OCD in patients with a minimum follow-up of 2 years.

MATERIALS AND METHODS

Since 1983, more than 400 patients have undergone fresh osteochondral allografting under Institutional Review Board approval at our institution. These patients were followed prospectively using a clinical database. Review of this database identified 66 knees in 64 patients who had undergone treatment for osteochondritis dissecans of the femoral condyle and had a minimum of 2 years of follow-up. Each patient was evaluated using an 18-point modified D'Aubigné and Postel scale (Table 1).[10] This scale allocates 6 points for absence of pain, 6 points for range of motion, and 6 points for knee function. A score of 18 is rated as "excellent" and indicates that the patient has complete relief of pain, has no limp, has a range of motion from 0° to 130° or more, and can perform unlimited work and most recreational activities. Fifteen to 17 is classified as a "good" outcome and typically allows full-time employment and moderate activity with occasional pain or swelling. A "fair" outcome is rated 12 to 14 and indicates that the patient has returned to work only with restrictions, has limitations in activity, often experiences swelling, has less than 90° range of motion, and frequently requires pain medication. "Poor" is any score less than 12 and indicates that the patient has decreased range of motion, constant knee pain, and a level of function that limits activities of daily living.[5,6] Reoperation was defined as allograft removal, revision of the allograft, unicompartmental knee arthroplasty, or total knee arthroplasty.

Patients were each given a follow-up survey evaluating current pain and functional status compared with the preoperative period. Overall satisfaction with the allograft surgery and willingness to undergo a similar procedure again under similar circumstances were also determined.

When available, preoperative, immediate postoperative, and most recent follow-up anteroposterior and lateral radiographs were reviewed. Evidence of graft union, collapse, resorption, and the presence of degenerative changes was recorded by a musculoskeletal radiologist. Long-cassette and standing films were evaluated when available. The degree of osteoarthritis was graded according to the modified Fairbank/Ahlback criteria as described by Lundberg and Messner.[23]

TABLE 1
Modified D'Aubigné and Postel 18-Point Scale

Pain	
1. Severe	Not relieved by rest and analgesics
2. Severe	Relieved by rest and analgesics
3. Moderate	Regular analgesics needed
4. Mild	Occasional analgesics needed
5. Minimum	Occasional ache
6. None	
Function	
1. Bedridden or household walker with 2 canes or crutches	
2. Time and distance outside limited; walks with canes or crutches	
3. Walks <0.8 km with external aids; going up and down stairs limited	
4. Walks >0.8 km with or without external aids; going up and down stairs not limited	
5. No canes; limps	
6. Unlimited walking without a limp	
Range of motion	
1. <60° of flexion	
2. 15° to 90° of flexion	
3. 0° to 90° of flexion	
4. >90° of flexion; ≤15° extension lag	
5. >90° of flexion without extension lag	
6. ≥130° of flexion without extension lag	

Surgical Technique

Before the procedure, donor and recipient were matched solely on the basis of size using standard anteroposterior radiographs with a correction for magnification. No immunologic parameters were compared, and no immunosuppressive therapy was used.[5] Fresh anatomical donor tissue was obtained from healthy donors who met the criteria of the American Association of Tissue Banks. Donor tissue was recovered within 24 hours of expiration and then maintained at 4°C until the time of implantation. Until recently, each graft was implanted within 5 to 7 days of procurement. This period was extended at the end of the study, however, and tissue is now stored for a minimum of 14 days and a maximum of 28. This allows final bacterial cultures to be analyzed before implantation.

Surgery was performed through a full or mini-arthrotomy. The area to be grafted was modified into a geometric shape, and the defect was prepared down to a depth of 2 to 10 mm. For small and medium-sized lesions, a dowel technique was used (Figure 1). A shell allograft technique was used for larger lesions (Figure 2). To decrease the immunogenicity of the graft, pulsatile lavage was used to remove the potentially immunogenic marrow elements from the osseous surface. The graft was tailored into a shape matching the lesion, and trial fittings were performed. After the graft had been properly positioned, fixation was achieved

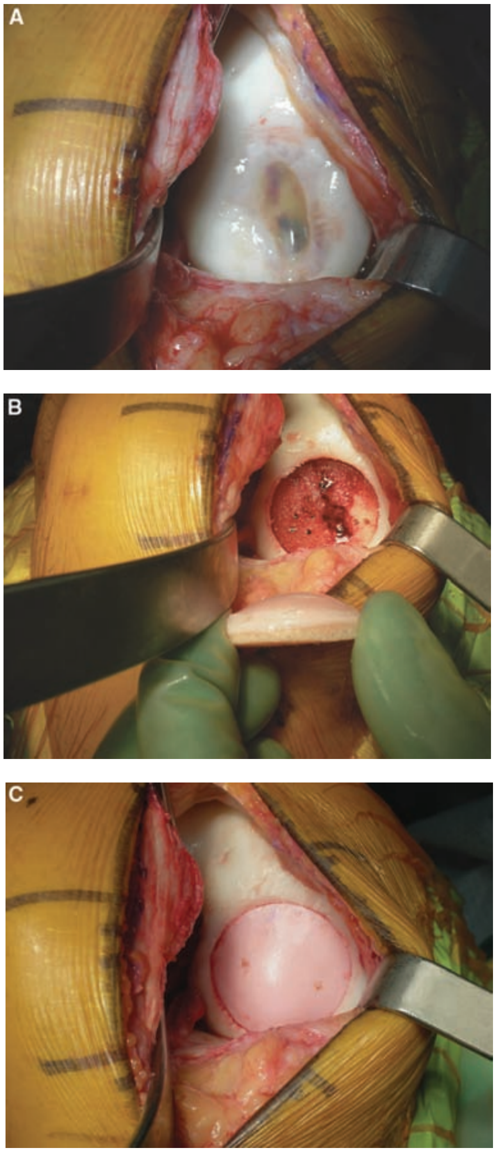

Figure 1. Osteochondral allograft dowel technique. A, a mini-arthrotomy is performed, and the osteochondritis dissecans lesion is identified. B, the diameter of the defect is measured, and the lesion is prepared down to a depth of 2 to 10 mm. C, the allograft is fashioned into a cylindrical plug and inserted into the defect. Temporary fixation is achieved with absorbable polydioxanone pins when indicated.

using both press-fit and absorbable polydioxanone pins (Johnson & Johnson, Raynham, Mass) when indicated.[5, 6]

Postoperative care included the use of continuous passive motion while the patient was hospitalized to maximize cartilage nutrition and routine physical therapy with 3 months of protected weightbearing. Closed-chain exercises were begun at 4 weeks and unrestricted activities of daily living at 3 to 4 months. The patient was generally allowed to return to sports, recreation, and physical labor between 4 and 6 months.[5]

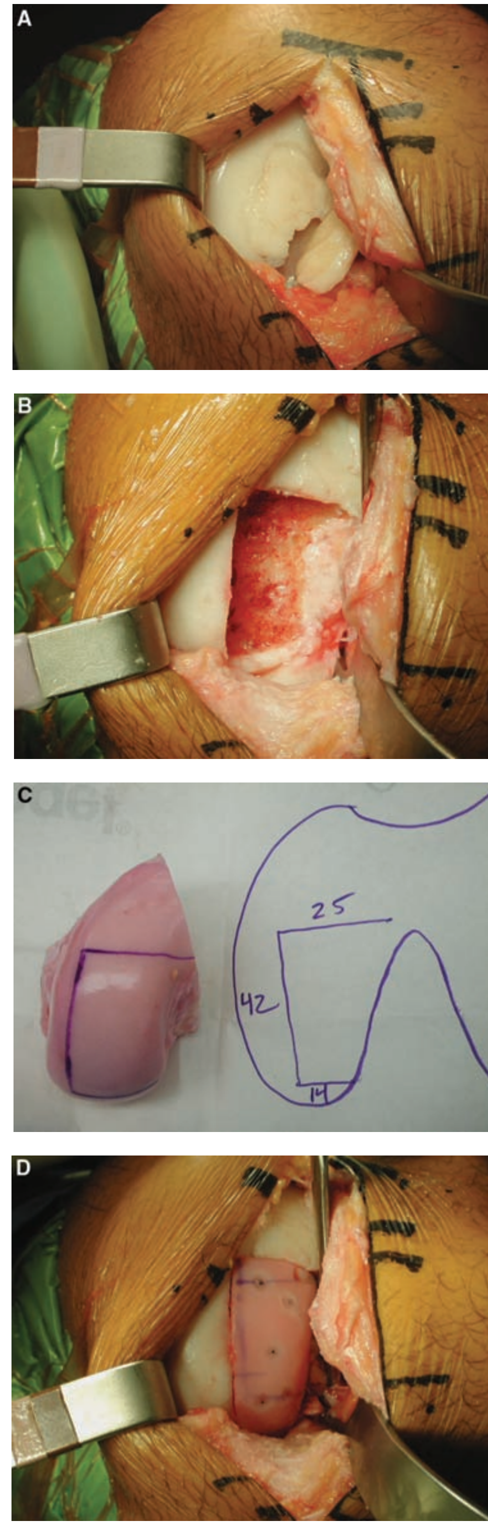

Figure 2. Osteochondral allograft shell technique. A, a mini-arthrotomy is performed, and the osteochondritis dissecans lesion is identified. B, the defect is modified into a geometric shape, and the lesion is prepared down to a depth of 2 to 10 mm. C, the defect is measured, and a template is applied to the allograft. D, the allograft is cut to match the template and then inserted into the defect. Temporary fixation is achieved with absorbable polydioxanone pins.

Statistical Methods

Preoperative and postoperative modified D'Aubigné and Postel scores were analyzed using the paired *t* test (SSPS Inc, Chicago, Ill). Kaplan-Meier[20] survival analysis was calculated using SAS statistical software (SAS Institute, Cary, NC). Statistical significance was set at $P < .05$.

RESULTS

Sixty-six knees in 64 patients underwent fresh osteochondral allografting for the treatment of osteochondritis dissecans between 1980 and 2003. Mean follow-up of the 66 knees was 7.7 years (range, 2-22 years). There were 45 men and 19 women with a mean age of 28.6 years (range, 15-54 years). Forty-one lesions involved the medial femoral condyle, and 25 involved the lateral femoral condyle. An average of 1.7 surgeries had been performed on each knee before the allografting procedure. The most common prior surgery was arthroscopic loose body removal. The mean allograft size was 7.5 cm^2. One patient underwent ACL reconstruction at the time of allografting, and no patients underwent a corrective osteotomy.

One patient was lost to follow-up. Of the remaining 65 knees, 47 (72%) were rated good/excellent, 7 (11%) were rated fair, and 1 (2%) was rated poor. The mean D'Aubigné and Postel score improved from 13.0 ± 1.7 preoperatively to 16.4 ± 2.0 at the most recent follow-up ($P < .01$) (Figure 3). Ten patients (15%) underwent reoperation after the initial allografting procedure (Table 2). Five of these patients underwent revision fresh osteochondral allografting at 1, 2, 6, 7, and 8 years. One patient received a second osteochondral allograft in the ipsilateral knee but at a site separate from the original OCD lesion. One patient was converted to a total knee arthroplasty 3 years postoperatively. One patient underwent a revision fresh osteochondral allograft at 5 years and then had a subsequent total knee arthroplasty performed 8 years after the index operation. One patient underwent a unicompartmental knee arthroplasty after 5 years. Lastly, 1 patient had the allograft arthroscopically removed at 7 years. Kaplan-Meier survival analysis demonstrated 91% survivorship at 5 years (95% confidence interval, 83% to 99%) and 76% survivorship at both 10 and 15 years (95% confidence interval, 62% to 90% at both time points).

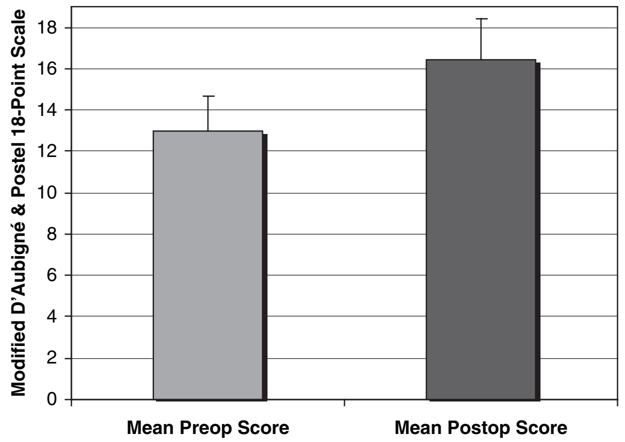

Figure 3. Preoperative and postoperative comparison of the modified D'Aubigné and Postel 18-point scale. The results are shown as mean values with standard deviation error bars ($P < .01$).

Postoperative radiographs were obtained in 29 of 66 knees, with a mean radiographic follow-up of 3.3 years (Figure 4). Twenty-one (72%) of the grafts demonstrated healing, and 23 (79%) were intact. Subchondral cysts were present in 5 (17%) knees. Sclerosis was found in 6 (21%) cases. In the medial compartment, 5 knees (17%) were found to be grade 0, 7 (24%) had grade I osteoarthritis, 14 (48%) were grade II, and 3 (10%) were grade III. In the lateral compartment, 15 (52%) were grade 0, 9 (31%) had grade I changes, 3 (10%) were grade II, and 2 (7%) had grade III osteoarthritis.

At their most recent follow-up, 59 of 64 patients completed patient questionnaires. Fifty-four (92%) were satisfied with their treatment, and 53 (90%) reported less pain. When patients were asked to subjectively compare their

TABLE 2
Final Surgical Outcomes for the 10 Patients Who Underwent Reoperation[a]

Age, y	Size, cm^2	Time to Reoperation, mo	Surgery	Current Score
16	20.8	12	OCA revision	15
38	10.4	23	OCA revision	13
16	2.2	32	OCA same knee, but separate lesion	18
30	16.2	36	TKA	13
36	14.0	60	OCA then TKA	14
54	7.1	66	UKA	15
22	10.6	72	OCA revision	16
33	8.1	84	OCA revision	16
36	7.5	85	OCA removal	16
31	7.4	93	OCA revision	16

[a]OCA, osteochondral allograft; TKA, total knee arthroplasty; UKA, unicompartmental knee arthroplasty.


Figure 4. Preoperative anteroposterior (A) and lateral (B) radiographs demonstrating osteochondritis dissecans lesion of the medial femoral condyle. Standing left knee anteroposterior (C) and lateral (D) postoperative radiographs 12 years after allograft surgery. This patient scored 18 points at his most recent follow-up. Some medial joint space narrowing is evident, but the graft is noted to be well incorporated in the medial femoral condyle.

current knee function with that before allograft surgery, we found that they had improved from a mean of 3.4 ± 1.9 to 8.4 ± 1.5 on a 10-point scale ($P < .01$) (Figure 5). When asked if they would undergo the same operation again under similar circumstances, 51 (86%) patients stated that they would.

DISCUSSION

As part of a comprehensive osteochondral transplant program at our institution, fresh osteochondral allografts were used to treat 66 adult knees with OCD of the femoral condyle that had not responded to other conservative or surgical management. In our experience, fresh osteochondral allograft transplantation has been a successful surgical treatment for OCD of the femoral condyle. Fresh allograft transplantation allows for both the resurfacing of large osteochondral defects with mature hyaline cartilage and the replacement of diseased or absent subchondral bone.[5]

The presence of an OCD lesion in an otherwise healthy knee provides a clinical environment that is well suited to the use of fresh osteochondral allografting.[28] Garrett[12] described OCD lesions as the ideal situation for the use of an osteochondral allograft because the lesions are typically unipolar, large, and well circumscribed. Early investigation illustrated that allografts function best when a single articular surface is replaced, the surrounding ligaments are intact, the menisci are normal, and the alignment is normal.[12] Aubin et al[1] also noted that osteoarthritis or the presence of disease on both articular surfaces is a contraindication to fresh allograft transplantation. In their review of osteochondral allografts used to reconstruct posttraumatic osteochondral defects in 126 knees, Ghazavi et al[13] demonstrated that factors related to failure included age greater than 50 years, bipolar defects, malaligned knees, and workers' compensation. In our study only 1 patient was noted to have a preoperative valgus deformity, and no patients underwent corrective osteotomy. At the beginning of the study, preoperative alignment films were not routinely performed. In recent years, however, the use of alignment radiographs has been included in the preoperative evaluation, and osteotomies are being performed with greater frequency at our institution in concert with fresh allografting to correct both osteochondral defects and malalignment. Those patients who had corrective osteotomies performed were not included in this study because they had not met the minimum required follow-up of 2 years. One patient did undergo an ACL reconstruction at the time of allografting. All lesions

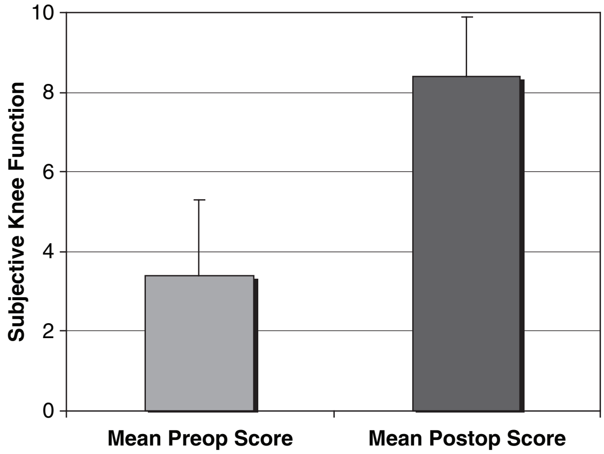

Figure 5. Preoperative and postoperative comparison of subjective knee function on a 10-point scale. The results are shown as mean values with standard deviation error bars ($P < .01$).

were unipolar and did not involve significant disease of the tibial plateau.

Several surgical techniques have been proposed for treatment of focal cartilage defects of the femoral condyle. The microfracture technique involves perforation of the subchondral bone at the base of a chondral lesion to stimulate the formation of fibrocartilage tissue.[37,38] Successful outcomes have been correlated with defects of less than 4 cm^2.[21] Microfracture has the advantage of being less invasive and relatively inexpensive.[7] It is, however, best suited to small lesions without extensive involvement of the subchondral bone.[14] Microfracture is often considered a reasonable first approach to chondral defects because it does not preclude further treatment with other procedures.[37]

Osteochondral autograft transfer (OATS) has also been used to treat OCD lesions with reported success.[18,24] This technique has the significant advantages of restoring the surface defect with the patient's own mature hyaline cartilage as well as replacing the underlying subchondral bone. The lack of available donor cartilage limits the use of this technique to relatively small lesions, however. In addition, the harvest site is not without a potential for morbidity.[18,24] Horas et al[18] demonstrated viable hyaline cartilage present 22 months after osteochondral allograft transfer. They advocated autologous osteochondral cylinder transplantation for smaller lesions and osteochondral allografts for larger lesions. Similarly, Wang[39] reported poor results when osteochondral autografting was used to treat lesions larger than 6 cm^2.

Autologous chondrocyte implantation (ACI) was introduced in Sweden in 1987, and the outcome of the first trial was published in 1994.[3] This technique involves harvesting chondrocytes from the knee, multiplying these cells in culture, and then implanting the cultured cells in the chondral defect beneath a periosteal flap.[3,4,27,32] Peterson et al[32] reported greater than 90% success using ACI to treat 58 patients with OCD lesions of the femoral condyles with a mean follow-up of 5.6 years. At 5.7 cm^2, the average lesion size in Peterson's study was somewhat smaller than the average lesion size in our study, however. Similarly, Minas[26] treated 169 patients with autologous chondrocyte implantation for focal chondral defects of the knee with an 87% success rate. Of these patients, 12 were treated for isolated unipolar lesions of the femoral condyle with a 60% satisfaction rate. Again, the average lesion size in this study was somewhat smaller at 4.5 cm^2. In addition, although the early reports were promising, more recent literature suggests that outcomes from ACI may not be superior to the outcome of microfracture.[21]

The lesions in our study were large, full-thickness defects with an average size of 7.5 cm^2. The vast majority of lesions in this series were too large for microfracture or an OATS procedure to be effective. In addition, the average knee had already undergone a mean of 1.7 such procedures before allografting. Although ACI is also indicated for large focal lesions, this procedure does not replace the subchondral defect.[32] Both Aubin et al[1] and Gross et al[14,15,17] recommended the use of fresh osteochondral allografts for defects larger than 3 cm in diameter or 1 cm in depth because of the magnitude of cartilage and subchondral bone that are missing.

The use of fresh donor tissue has been extensively studied and appears to be superior to the use of frozen allografts.[34,35] Although cryopreservation offers the advantage of decreased antigenicity[34] and eases the storage and transportation between facilities, freezing donor tissue has been shown to severely limit the viability of the chondrocytes to be implanted.[30,34] Both freeze-drying and irradiation have been shown to significantly reduce the torsional and bending strength of the graft.[31] Fresh allografts have consistently shown increased chondrocyte viability both in vitro[34,35] and in vivo.[9] Czitrom et al[9] showed histologic viability of chondrocytes in fresh allografts retrieved up to 6 years after transplantation. Similarly, Convery et al[8] demonstrated the presence of hyaline cartilage and chondrocyte viability in a fresh allograft retrieved 10 years after implantation. Gross and colleagues confirmed hyaline cartilage with viable chondrocytes in specimens harvested 7, 8, and 17 years after implantation of a fresh allograft.[16,25] In contrast, Enneking and Campanacci[11] found no viable chondrocytes in 24 of 28 retrieved frozen osteoarticular allografts.

Although chondrocytes have been shown to be immunogenic, experimental evidence has indicated that the matrix protects intact allograft cartilage from the host's immune system. The experiments of Langer and Gross[22] provide evidence that the matrix polysaccharides prevent exposure of the graft chondrocytes to the tissue and fluids of the host. This allows the graft to potentially survive indefinitely as the chondrocytes are nourished by synovial fluid and the osseous portion of the graft is integrated into the host by revascularization and creeping substitution.[9] In addition, graft storage at 4°C for 12 or 24 hours has been shown to significantly decrease immunogenicity.[34]

The use of fresh allografts highlights the importance of having high-quality fresh tissue available. This requires

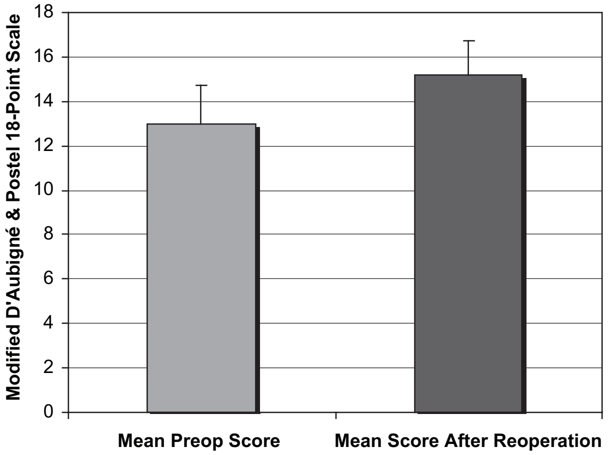

Figure 6. Preoperative and postoperative comparison of the modified D'Aubigné and Postel 18-point scale in patients who underwent reoperation. Despite additional surgery, these patients showed significant improvement over their initial presentation. The results are shown as mean values with standard deviation error bars ($P < .02$).

both the surgeon and the hospital to have a close working relationship with a tissue bank experienced in evaluating, handling, and processing this tissue under the guidelines established by the American Association of Tissue Banks.

In this study, good or excellent results were achieved in 72% of knees at a mean follow-up of 7.7 years. Likewise, osteochondral allografting has been shown to have a high degree of success in several other studies. Chu et al[6] reported that in 8 patients diagnosed with OCD and treated with unipolar fresh articular cartilage replacements, all were rated as good or excellent. Similarly, Garrett[12] reported success with 16 of 17 grafts in patients with OCD lesions of the lateral femoral condyle at 2 to 9 years after surgery. In their review of osteochondral allografts used to reconstruct posttraumatic osteochondral defects in 126 knees, Ghazavi et al[13] rated 108 knees (85%) as successful and had 18 failures (15%).

The mean 18-point D'Aubigné and Postel score increased from 13.0 preoperatively to 16.4 at the most recent follow-up, a statistically significant difference ($P < .01$). Kaplan-Meier survival analysis demonstrated 91% survivorship at 5 years and 76% at both 10 and 15 years. Similar results have been reported by several authors evaluating patients with posttraumatic knee defects at Mount Sinai hospital in Toronto. Aubin et al[1] and Gross et al[17] demonstrated 95% survival at 5 years, 85% allograft survival at 10 years, and 74% at 15 years. Ghazavi et al[13] calculated survivorship analysis and showed 95% graft survival at 5 years, 71% at 10 years, and 66% at 20 years. Beaver and colleagues[2] demonstrated good clinical results in 75% of patients with fresh unipolar allografts for posttraumatic defects of the knee at 5 years. At 10 years, the success rate was 70%.

Because many patients traveled significant distances to undergo allograft surgery, radiographic follow-up was limited. Although not complete, the available images demonstrated reliable radiographic healing and incorporation of the grafts. A small percentage of patients showed the presence of sclerosis or cysts, suggesting incomplete healing.

An important aspect of the use of osteochondral allografting is that failure does not preclude other reconstructive procedures. Should the graft fail, further treatment options include a second graft procedure or arthroplasty.[5,12] In this study, 10 patients required further surgery on their previously operated knee, with a mean time to reoperation of 56 months. Typically, allograft failure occurred because of collapse and fragmentation of the osseous portion of the graft. The cartilage surface was generally noted to appear healthy at the time of reoperation. Older patients with failed allografts were converted to a total knee arthroplasty with little difficulty. These procedures did not require any specialized augmentations or advanced arthroplasty techniques.

Those patients who underwent reoperation tended to be older, with a mean age of 31 years at the time of the index procedure. In addition, the lesions tended to be larger, with an average size of 10.4 cm^2. In this study, both the oldest patient at 54 years and the patient with the largest graft at 20.8 cm^2 underwent reoperation. Of note, the mean D'Aubigné and Postel score of the reoperation group was 15.2 ± 1.5 at most recent follow-up. Despite reoperation, this represents a significant improvement compared with their score before the original allograft surgery ($P < .02$) (Figure 6).

Criticism of this study lies largely in the use of the modified D'Aubigné and Postel 18-point scale. Although it provides information with regard to pain, range of motion, and knee function, it has not been statistically validated for use in the knee. When this study was initiated more than 20 years ago, the 18-point scale provided the only objective clinical preoperative data that were recorded. It is for this reason that we report on it here. International Knee Documentation Committee and SF-36 data are now being collected. Additionally, although patients were enrolled and evaluated prospectively, there was no control group or alternative treatment group. This makes comparisons with other treatments difficult. The series of patients reported on here had failed all previous surgical interventions, and fresh osteochondral allografting was considered their final option. Lastly, the limited amount of radiographic follow-up meant that no statistically significant comparisons could be made. Rather, these results provide only a limited, descriptive assessment of findings.

With a success rate of greater than 70%, fresh osteochondral allograft transplantation is a successful surgical treatment for OCD of the femoral condyle. Fresh osteochondral allografts are able to restore both osseous and chondral deficiencies with anatomically appropriate tissue and remain an important treatment option for young, active individuals with large OCD lesions of the femoral condyle. Importantly, allograft failure does not preclude further reconstructive surgery.

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