Triad of Cartilage Restoration for Unicompartmental Arthritis Treatment in Young Patients

Meniscus Allograft Transplantation, Cartilage Repair, and Osteotomy

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ABSTRACT: Arthritis treatment in young patients remains a challenge. Joint replacement surgery offers excellent pain relief but is controversial with this age group because of long-term wear and loosening. Recently, biological reconstructive techniques have become available to improve traditional treatment methods such as osteotomies. We present our experience with a technique for combined meniscal transplantation, chondral repair, and osteotomy in 7 patients presenting with a constellation of meniscal deficiency, focal arthritis, and malalignment.

Patients underwent concurrent or staged meniscal transplantation, cartilage repair, and osteotomy. Evaluation included the International Knee Documentation Committee (IKDC) score, Knee injury and Osteoarthritis Outcome Score (KOOS), and Short Form-12 and Lysholm scales. At average follow-up of 24 months, patients experienced significant improvements in the IKDC, Lysholm, and KOOS functional scores. Six of 7 patients were able to return to unrestricted activities; 1 patient experienced mild pain with high-impact activities. Combined treatment with meniscal transplantation, cartilage repair, and osteotomy demonstrated promising clinical results of unicompartmental arthritis treatment in young patients.

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INTRODUCTION

Unicompartmental arthritis is a known outcome in 30% to 70% of patients after near-total loss of meniscal tissue, with a relative risk of up to 14 times when compared with matched controls.[10,12,13] Worse outcomes are associated with youth, associated chondral damage, ligamentous instability, and malalignment.[3,9] Although arthroplasty yields excellent results, young and active patients <45 years are less willing to undergo it because of associated activity restrictions,[5] and thus traditionally have been treated instead with joint-preserving procedures, such as osteotomies.[14] In this patient population, good to excellent results have been reported in up to 70% of patients at 10 years after high tibial osteotomy.[8] However, to obtain good results, large correction angles are required,[6] which are considered poorly tolerated in young patients who wish to remain active. In addition, many patients continue to experience activity-related pain and effusions due to persistent intra-articular pathology.

More recently, meniscal allograft transplantation has been popularized for the treatment of symptomatic meniscectomized knees, performed either in isolation or in conjunction with osteotomy.[4,11] Although good results have been reported, meniscal allograft transplantation traditionally has been contraindicated in patients with full-thickness cartilage defects,[1] thus excluding many patients who are usually symptomatic and could potentially benefit most from this procedure. Modern cartilage repair procedures such as autologous chondrocyte implantation and osteochondral allograft transplantation can address such defects during meniscal allograft transplantation. In addition, they have the potential to improve outcomes even in patients presenting with more advanced degenerative changes.[7] Similarly, conducting a realigning osteotomy will help mitigate reinjury or overload of the transplanted meniscus.[2]

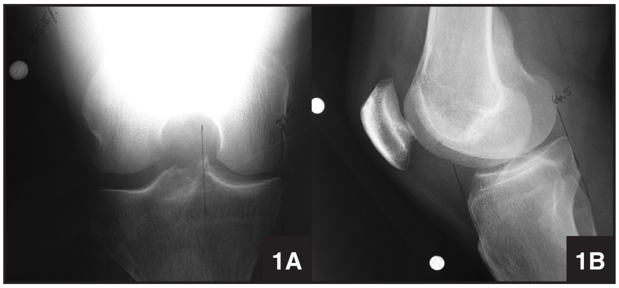

Figure 1. AP (A) and lateral (B) sizing radiographs demonstrating markings used to calculate graft dimensions for meniscal transplantation.

We describe a subgroup of patients presenting with abnormalities that significantly increase the risk of early-onset symptomatic osteoarthritis. This triad consists of prior total or subtotal meniscectomy, high-grade chondral defects, and lower extremity malalignment.

MATERIALS AND METHODS

History and Physical Findings

Between 2001 and 2005, 7 patients were treated at our facility for ipsilateral chondral defects and meniscal deficiency, refractory to other methods such as nonoperative treatment or arthroscopic debridement. None of the study patients had ligamentous insufficiency.

Patients reported a history of total or subtotal meniscectomy, resulting in near-complete resolution of pain for a few months to several years, after which activity-related joint line pain and swelling recurred. The majority of patients underwent additional procedures (ie, repeat meniscectomies, debridement of cartilage) but ultimately failed conservative and conventional surgical treatment.

Typical physical examination findings included activity-related swelling and joint effusion, joint line tenderness and mild laxity due to loss of cartilage, and meniscal tissue with preserved range of motion.

Imaging

Radiographs included standard weight-bearing anteroposterior (AP), 45° flexion posteroanterior, lateral, and axial sunrise views. Double-stance, weight-bearing long-leg radiographs were obtained to assess alignment. Magnetic resonance imaging was used to evaluate the chondral, meniscal, and ligamentous structures and to rule out or define associated pathology. Magnetic resonance imaging also frequently showed evidence of compartment overload, such as reactive subchondral edema.

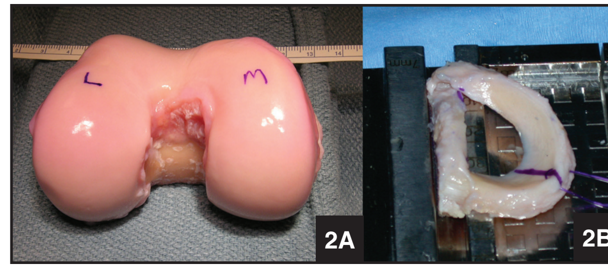

Figure 2. Allograft tissue. A fresh donor osteochondral allograft femoral condyle (A). Usually, a hemicondyle is adequate for most defects. Prepared meniscal allograft (B). The bone block has been sized to fit the trough created on the tibial plateau, and a #1 polydioxanone suture has been attached to the junction of the middle and posterior third to help reduce the graft under the femoral condyle.

SURGICAL TECHNIQUE

We performed the order of reconstructive procedures on the basis of the cartilage repair technique used. Osteochondral transfer or allograft transplantation can be performed at any time during the procedure; however, due to the delicate nature of the periosteal graft, autologous chondrocyte implantation should be performed last. Osteotomy should be performed after meniscal allograft transplantation because the significant abduction or adduction moments required during meniscal transplantation can damage the osteotomy.

Patients underwent concomitant or staged meniscal allograft transplantation, osteotomy, and cartilage repair, as indicated by the size and location of the chondral lesion. Several factors should be considered when deciding whether to perform a staged versus a concomitant approach to address comorbidities: staging requires multiple interventions and, therefore, several recuperative periods; concurrent reconstruction requires less time spent on recuperation but, due to the increased trauma of multiple concurrently performed procedures, results in increased surgical time and risk of complications, such as stiffness. Patient preferences, surgeon experience, logistics, and the clinical presentation should be considered when determining which approach to adopt.

Meniscal Allograft Transplantation

Meniscal allograft transplantation was performed in all cases using a size-matched and side-matched frozen graft with attached bone block. Briefly, meniscal dimensions were determined from preoperative radiographs. Accounting for magnification, the distance between the ipsilateral tibial spine and the edge of the tibial plateau on the AP radiograph was measured to provide graft width. Graft length was calculated by measuring the distance between

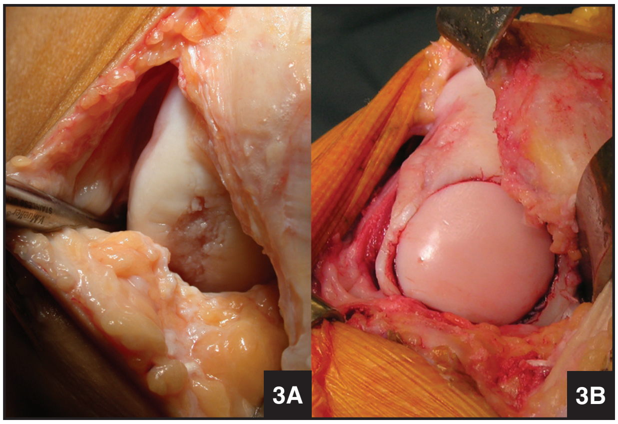

Figure 3. Condylar chondral defect before (A) and after (B) press-fit placement of a fresh osteochondral allograft dowel.

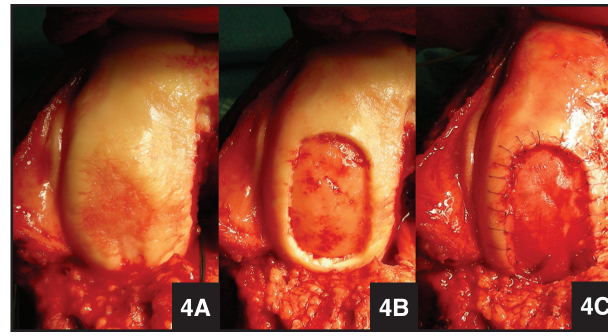

Figure 4. Condylar chondral defect before (A) and after (B) preparation. The defect was covered with a patch (C).

the anterior and posterior edge of the tibial plateau on the lateral radiograph, multiplied by 0.7 for lateral and 0.8 for medial grafts (Figure 1). We prefer the bridge-in-slot technique for both medial and lateral meniscal allograft transplantation, which uses a 7-mm to 8-mm-wide bone bridge for secure graft fixation on the tibial plateau (Figure 2). In our experience, this has provided secure fixation and preserved the relationship of the anterior and posterior meniscal horn attachments. The original meniscus is arthroscopically debrided down to a 1-mm to 2-mm rim of bleeding tissue. A 3-cm to 4-cm longitudinal transpatellar incision provides access to create a recipient slot inline with the original meniscal horn attachment sites, which effectively removes part of the ipsilateral tibial spine. Prior to creation of the slot for a medial meniscal transplant, the most medial fibers of the tibial anterior cruciate ligament insertion are partly released off the tibial spine. The bone bridge is introduced into the recipient slot, and the attached meniscus is reduced under the femoral condyle through application of the appropriate varus or valgus stress. Secure fixation of the bone bridge is achieved with a resorbable interference screw, and peripheral fixation is performed following established meniscal repair principles with 10 to 12 sutures using accessory posteromedial or posterolateral incisions.

Cartilage Repair

Depending on size and location of the chondral defect, arthroscopic or open approaches may be used: Smaller lesions (<4 cm^2) are amenable to microfracture or osteochondral autograft cylinder transfer, whereas larger lesions (>4 cm^2) require arthrotomy for osteochondral allograft transplantation or autologous chondrocyte implantation. Microfracture and osteochondral autograft transfer are indicated for small to midsize lesions and have been extensively described in the literature. Osteochondral allograft transplantation (Figures 2 and 3) is indicated for chondral lesions that are very large, uncontained, or deep. The defect is measured with a sizing guide, and then reamed to a depth of approximately 7 mm. An osteochondral dowel of similar curvature and dimensions is harvested from a size-matched and side-matched fresh allograft condyle and press-fit into the recipient hole. If secure fixation cannot be achieved through press-fit alone, resorbable pins can be added. Finally, autologous chondrocyte implantation is a 2-stage procedure in which a cartilage biopsy first is harvested arthroscopically and subsequently is expanded in cell culture. After 6 weeks, the cells are reimplanted through an arthrotomy (Figure 4). The lesion is debrided to create stable, vertical shoulders with removal of intralesional osteophytes or, when necessary, sclerosis of the subchondral bone. A periosteal flap is harvested from the anteromedial surface of the tibia and sutured to the cartilage surrounding the defect. Uncontained defects occasionally require the use of microsuture anchors for supplemental fixation. After the periosteal flap is secured with multiple sutures, the now-covered defect is tested for watertightness. Additional sutures and fibrin glue are used to seal any leakage from the suture line. Finally, the cells are resuspended and injected into the defect.

Osteotomy

Osteotomies are generally performed on the femoral side to correct valgus deformities and on the tibial side for varus malalignment. Preoperative alignment radiographs are used to calculate the required degree of correction: after measuring the width of the tibial plateau, a mark is placed at a width of 62% from the medial or lateral side, dependent on the desired direction of correction. Lines are drawn from this mark to the centers of the femoral head and talus. The required angle of correction is formed by the intersection of these lines.

We generally prefer opening wedge osteotomy, as it requires less operative time and can be adjusted more easily intraoperatively in both the sagittal and coronal

TABLE

PREOPERATIVE ALIGNMENT, CARTILAGE DAMAGE, AND PROCEDURES

Patient No.	Preoperative Alignment	Cartilage Damage	Type of Procedure: Osteotomy	Type of Procedure: Meniscus Transplant	Type of Procedure: Cartilage Repair	Postoperative Alignment
1	7° varus	Medial femoral condyle 2×2cm, Grade II	HTO	Medial	Microfracture, osteochondral allograft transplantation	2° valgus
2	7° varus	Tibial plateau 2×2cm, Grade III; medial femoral condyle 2×2 cm, Grade III	HTO	Medial	Microfracture, osteochondral allograft transplantation	Neutral
3	7° varus	Medial femoral condyle 2×2 cm, Grade IV	HTO	Medial	Osteochondral allograft transplantation	Neutral
4	8° varus	Medial femoral condyle 2.5×2.5 cm, Grade IV	HTO	Medial	Osteochondral allograft transplantation	Neutral
5	6° varus	Medial femoral condyle 2.4×2 cm, Grade III	HTO	Medial	Autologous chondrocyte implantation	Neutral
6	7° valgus	Lateral femoral condyle 1.1×1.1 cm, Grade IV	Distal femoral osteotomy	Lateral	Osteochondral autograft transplantation	Neutral
7	6° valgus	Tibial plateau 8×8 mm, Grade IV; lateral femoral condyle 2×2 cm, Grade IV	Distal femoral osteotomy	Lateral	Microfracture, osteochondral allograft transplantation	Neutral

Abbreviation: HTO, high tibial osteotomy.

planes. In the proximal tibia, opening wedge osteotomy also protects the proximal tibiofibular joint and peroneal nerve and complicates subsequent arthroplasty to a lesser degree than does closing wedge osteotomy. In the femur, opening wedge osteotomy is performed through a lateral approach, which is located away from the medial neurovascular structures. Usually, we graft osteotomies with structural allograft wedges and cancellous autograft from the distal femur or proximal tibia to lower the risk of nonunion. The autograft is obtained, for example, with an OATS harvester (Osteochondral Autologous Transfer System; Arthrex Inc, Naples, Fla) to take several cores of bone, which can be mixed with cancellous allograft chips and demineralized bone matrix and packed into the osteotomy site.

POSTOPERATIVE PROTOCOL

Patients remain nonweight bearing in a hinged knee brace and perform daily continuous passive motion treatments for 6 hours per day for 6 weeks. Motion is not restricted, with the exception of weight bearing flexion >90° to protect the meniscal repair. Seven to 10 days postoperatively, patients begin supervised physical therapy with gentle range of motion exercises and straight-leg quadriceps conditioning. After 6 weeks, weight bearing incorporates full and formal quadriceps strengthening into the program. Most activities of daily living are allowed after 3 months, with a return to noncontact, noncutting sports after 4 to 5 months. After 12 months, patients are allowed to return to unrestricted activities.

CLINICAL FOLLOW-UP

At each follow-up visit, assessments were performed according to multiple scoring systems including International Knee Documentation Committee (IKDC) score, Knee injury and Osteoarthritis Outcome Score (KOOS), and Short Form-12 (SF-12) and Lysholm scales. Objective measures included active range of motion and long-leg alignment films to determine the mechanical axis.

RESULTS

We present the results for 5 male and 2 female patients with a mean age of 32 years (range, 18-43 years). The mean time from injury to treatment was 18 months (range, 4-60 months). Follow-up averaged 24 months (range, 12-50 months). All patients had previous subtotal or total meniscectomies and full-thickness chondral defects associated with malalignment; the mean preoperative varus and valgus alignment was 7° and 6.5°, respectively (Table). There were 2 complications: a superficial wound infection occurring 1 week postoperatively and treated successfully with intravenous antibiotics, and a 1-cm wound dehiscence of a femoral osteotomy incision occurring 3 weeks postoperatively and successfully treated with oral antibiotics and wet-to-dry dressing changes.

Postoperatively, range of motion quickly returned in all patients and progressively increased from an average of 96° at 1-month follow-up to an average of 127° (range, 120°-135°) at the last follow-up.

Patients demonstrated significantly improved scores for the Lysholm scale (preoperatively: mean = 34; last follow-up: mean = 77; 129% increase, $P = .003$), IKDC score (26 preoperatively and 63 postoperatively; 138% increase, $P = .014$), KOOS-Pain (47 preoperatively and 84 postoperatively; 77% increase, $P = .010$), KOOS-Symptom (55 preoperatively and 74 postoperatively; 34% increase, $P = .038$), KOOS-Activities of Daily Living (53 preoperatively and 91 postoperatively; 74% increase, $P = .024$), and KOOS-Quality of Life (11 preoperatively and 48 postoperatively; 348% increase, $P = .018$). There were nonstatistical trends toward improvement in the KOOS-Sport and Recreation Function and SF-12 physical component summary and mental component summary subgroups. Of our 7 patients, 6 were able to return to full activities without restrictions and 1 has mild symptoms while playing basketball.

DISCUSSION

The treatment of unicompartmental arthritis remains controversial. Good results have been reported with a number of established treatment options, including injections, bracing, osteotomy, and arthroplasty. However, younger patients and those who wish to remain active are often dissatisfied with the associated restrictions. Advanced techniques, such as cartilage repair and meniscal transplantation, have been introduced to reconstitute, rather than accommodate for, the loss of chondral and meniscal tissue. We encountered a subgroup of patients presenting with abnormalities, including meniscal deficiency, chondral damage, and malalignment, that collectively result in a strong predisposition for the rapid progression of osteoarthritis. This patient population is typically unresponsive to conventional treatment methods, and advanced techniques often fail unless they are performed in combination to address all pathological entities in a staged or concomitant fashion.

In our experience, meniscal allograft transplantation combined with cartilage repair and correction of malalignment yielded near-complete resolution of pain in all of our patients. Six of 7 patients were able to return to unrestricted activities at their pre-injury level, whereas 1 patient was symptomatic with impact activities, such as playing basketball. On average, all objective scores increased, with statistically significant increases observed in the majority. Therefore, younger high-demand patients with prior total or subtotal meniscectomy, high-grade chondral defects, and lower extremity malalignment that have failed conservative management are ideal candidates for the described reconstruction. However, patients need to be carefully counseled on expected, reasonable functional gains, as well as the long and involved rehabilitation process. With diligent adherence to the postoperative rehabilitation protocol and close monitoring with regular follow-up visits, this technique has demonstrated favorable results in a complex and demanding patient population.

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