

Complex Knee Reconstruction: Osteotomies, Ligament Reconstruction, Transplants, and Cartilage Treatment Options

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ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION AND DEGENERATIVE JOINT DISEASE

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For every patient with an anterior cruciate ligament (ACL)-deficient knee combined with degenerative changes, it is important to identify surgical strategies that both optimize ACL reconstruction success and slow degenerative joint disease (DJD) progression. When these surgical strategies are incorporated with a complementary rehabilitation regimen, this patient group has the best possibility for an improved outcome for their condition.

Historical Overview

It has been reported by Noyes et al.¹ that most chronic ACL tear patients develop degenerative changes. In our experience, we have noted a significant number of these patients who report doing fine for many years, sometimes 15 years or more, before they present with pain without any associated recent injury event (Fig 1). Historically, moderate to severe degenerative changes were viewed as a contraindication to ACL reconstruction.² Concerns about postoperative stiffness were often cited and these concerns were often related to age. These patients generally fell into one of two groups and were either referred for a total knee replacement (TKR) or treated with conservative options.

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Previous Concepts: ACL Repair in a DJD knee

Various positions were previously taken regarding ACL repair in a DJD knee. In one study, the authors stated, "An increased incidence of degenerative joint disease [was found] in patients with [ACL] reconstructed knees."³ Out of the 5 possible explanations given for increased incidence of degenerative joint disease, the fourth, prolonged joint inflammation after surgery, is a prime factor. At the time this study was undertaken, arthroscopic ACL was in its infancy. Postoperative immobilization for 2 to 3 weeks was not uncommon during the interval this patient population's surgeries occurred from 1981 to 1989. This factor combined with autologous only graft use could have easily confounded the outcome assessment for this group of patients.

There may have been additional contributing factors. ACL reconstruction success is generally recognized as highly dependent on femoral tunnel placement. Perhaps the most significant work defining this issue was done by Fuss in 1991 (Fig 2). He reported that, prior to that time, many different femoral tunnel positions were used.⁴ Less well recognized is the importance of tibial tunnel placement.²⁰ For these reasons alone, studies before 1991 are suspect.

Previous Concepts: Conservative Option

The previous concept was that high-risk patients should be treated with early surgery and low-risk patients should be treated nonsurgically.⁵⁻⁷ However, Daniel et al. found that the patient with the ACL-disrupted knee is at risk of functional impairment, secondary meniscus tear, and the development of joint arthrosis.⁸ Dehaven found the incidence of meniscus tears after meniscus repair is higher in the ACL-disrupted knee than in the ACL-reconstructed knee.⁹ Daniel et al. and Andersson et al. found conservative

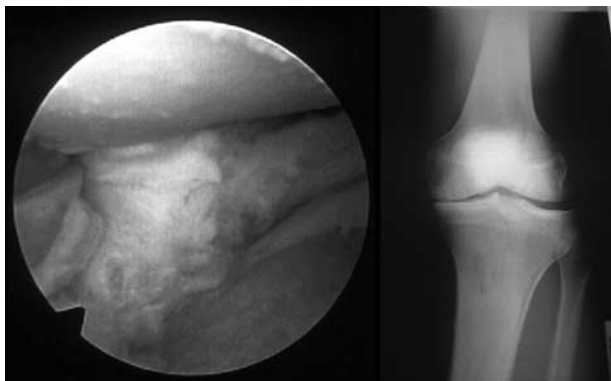


FIGURE 1. Conservative or delayed treatment. Many of these patients will report doing well for 15 or more years and then present with the changes seen above.

treatment produces a higher incidence of late meniscus tears in the ACL-disrupted knee versus the ACL-reconstructed knee.^{3,10} In Clancy's study, 44% of the nonreconstructed patients had a good or excellent result versus 97% with an ACL reconstruction.¹¹ Ciccotti et al. reviewed 30 patients, 40 years and older, with chronic ACL deficiency; 97% had 2+ to 3+ Lachman tests, 83% had a positive pivot shift, and 37% had a substantial re-injury.¹² Buss et al. followed 55 ACL-deficient patients (mean age, 30 years). This patient group had low occupational and athletic demands and they were considered good candidates for

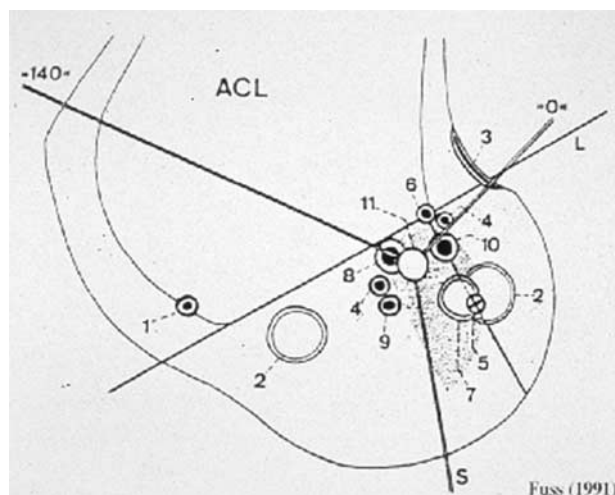


FIGURE 2. Position of the femoral graft insertion (according to these authors and their operation technique): 1 Jones (1963), 2 Alm (1973), 3 McIntosh (1974), 4 Artmann and Wirth (1974a), 5 Artmann and Wirth (1974b), 6 Tillberg (1977), 7 Clancy et al. (1981), 8 Hassenpflug et al. (1985), 9 Börner et al. (1988), 10 Schabus (1988), 11 Fuss (1991).

TABLE 1. Success With ACL Reconstruction in an Older Population

Group 1 (>40) n = 33
Group 2 (<40) n = 170
BTB allograft/autograft and Achilles allograft were used
Accelerated ROM rehabilitation protocol
KT-2000, Lysholm and Tegner comparisons indicated no difference between >40 v <40
KT-2000 (man/max)
Group 1, 1.5 mm
Group 2, 1.7 mm
Lysholm score
Group 1, 95
Group 2, 95
Tegner activity scale
Group 1, 5.7
Group 2, 6.

Data from Barber et al.¹⁴

conservative treatment. At follow-up, 40% reported recurrent giving way and 15% went on to have ACL reconstruction.¹³

New Concepts: Older Patient ACL Reconstructions

For many years, age (>40 years) was a contraindication for ACL reconstruction. In the past 5 years, ACL reconstruction has been routinely extended to middle-aged patients. A good example that illustrates success with ACL reconstruction in an older population is provided by Barber et al. in Table 1.¹⁴

If, as Barber's group ratio suggests, 1 of every 5 ACL patients is over 40 years of age, this age group of patients has grown from a group of nonsurgical option ACL patients to a very statistically significant group of ACL reconstructions. This study illustrated that athrofibrotic fears of the past are no longer supported with today's surgical and rehabilitation techniques and that functional stability can be restored in this group. The very worthwhile conclusion to be learned from these results is that age should not be seen as a contraindication to ACL reconstruction.

Previous Concepts: Pain, DJD, and Chronic ACL

Historically, moderate to severe DJD with associated ACL reconstruction has been a contraindication for reconstruction.² Patients with an ACL-deficient knee and DJD typically endured frequent episodes of giving way resulting in a marked reduction in activity level due to pain. Procedures were performed with the objective of buying time until the patient reached an appropriate age for arthroplasty. Osteotomy was the

primary solution for these patients when a significant lower extremity malalignment was present. And, if no malalignment was present, debridement, synovectomy, and osteophyte removal, were common treatments for these cases.

There are factors that may not have been previously considered that precluded the consideration of ACL reconstruction as an option for patients with combined ACL-deficient-DJD knees. In the presence of chronic DJD, successful clinical assessment of ACL deficiency is effectively masked by the DJD symptoms. Noyes and Barber, in their 1997 study, made 3 succinct observations on why surgeons may not reconstruct ACLs in the presence of DJD¹⁵:

1. Patients with chronic ACL deficiency and advanced articular cartilage deterioration often present with pain and swelling as their major complaints.
2. Full giving-way of the knee may be infrequent because the majority of these individuals have modified their activities, although partial giving-way may still occur with daily or light recreational activities.
3. A surgeon may be reluctant to reconstruct a deficient ACL when pain, and *not* instability, is the primary complaint.

Perhaps a fourth and fifth reason may be added. Surgeons may be reluctant to reconstruct a deficient ACL because of previous reports that reconstructing an ACL-deficient knee with DJD would make it worse.³ Surgical procedures for treatment of pain symptoms such as meniscectomy, chondroplasty, and abrasion arthroplasty can provide limited and short-term relief. Unfortunately, these procedures do *not* correct the primary problem of abnormal knee kinematics.

In active patients, the chronic ACL deficiency leading to DJD sequence of events is well known.¹⁶ This progression includes recurrent giving-way episodes, loss of secondary restraints, meniscal tears, and eventual chondral deterioration. Therefore, before deciding on a course of action, there are some issues worth considering during the treatment decision-making process for these patients. Should procedures, arthroscopic debridement and chondroplasty, be performed with the objective of buying time until the patient reaches the appropriate age for arthroplasty? Are a ligament reconstructive procedure and added rehabilitation period warranted for every patient presenting with these combined symptoms? What is the role of

ACL reconstruction in knees with advanced articular cartilage deterioration?

Clinical Strategies for ACL and DJD

There are some clearly defined clinical strategies for this patient group. It begins with preparing the patient and his or her physical therapist. Patients require additional education about their disease, their prognosis for success, and what to expect in terms of their rehabilitation time line and limitations during the rehabilitation process. It is extremely important that patients have reasonable expectations, rehabilitation milestones, and comparative benchmarks. In addition to defining the activities that they should not do, it is equally important to identify similar activity alternatives. Rehabilitation will take at least 1 year. Passive range of motion (ROM) exercises must be used. The patellofemoral joint must be protected and inflammation must be controlled.¹⁶ The most important factor necessary for successful ROM reacquisition is adequate follow-up and physical therapy. Follow-up and progress tracking will help identify and address, through physical therapy, those patients who may be struggling to regain ROM. Heel-slides and chair-sit ROM activities are recommended. Cryotherapy use may be required intermittently for the first year. It is very important to distribute the normal ACL rehabilitation cycle over a longer interval and to limit return to activities at appropriately tolerated levels. Swimming, stationary bicycling, and Nordic Track are recommended.

Educating the patient without training the physical therapist will prevent patient success. Physical therapists can be your best friend or your worst nightmare with your ACL-DJD patients. Teach them to *beware* of extension-against-resistance exercises. *Beware* of overloading the joint during repetitious flexion exercises. *Beware* of exercising when a joint is swollen. It is also important for both the patient and the physical therapist to understand that doing physical therapy for *short periods of time* with plenty of rest intervals is *better* than doing exercises for long periods until fatigued.

A correct preoperative diagnosis provides opportunity to prepare the patient for the consequences of his or her diagnosis and to provide him or her with details of a preoperative and postoperative plan that can be agreed upon before surgery occurs. Symptom diagnosis under circumstances where pain is often the major common complaint, and not instability, will rely heavily on patient history as well as the physical examination. ACL patients present primarily with

instability whereas DJD patients present primarily with *pain*. Consequently, ACL patients with DJD present primarily with pain and may *not* be unstable.

Full reviews of radiographs will likely present signs of secondary osseous changes and some variation in comparative alignment (Fig 3). Magnetic resonance imaging can be used but may be inconclusive. A possible anterior subluxation with lateral deviation of tibia may be a contra-indication. Patients may relate historical complaints of swelling and progressive ROM loss. During the course of obtaining knee condition and event history, pay particular attention to incidences of old injuries or surgery. While gross laxity may not present, it is important nonetheless, to perform the pivot shift¹⁷ and Lachman¹⁸ tests because combined trace positive signs for both in a degenerative knee may well indicate a chronic ACL deficiency.

Surgical Strategies for ACL and DJD

Prevention of degenerative changes is a key component of minimizing the number of ACL with DJD patients seen during a surgeon’s lifetime. This goal is accomplished by reconstructing acute ACLs before they cause additional injury. Sooner is better than later and later is better than never. If this option has been missed then the surgery goals are illustrated in Fig 4.



FIGURE 3. Secondary osseous changes may present. Note the variation in comparative alignment.

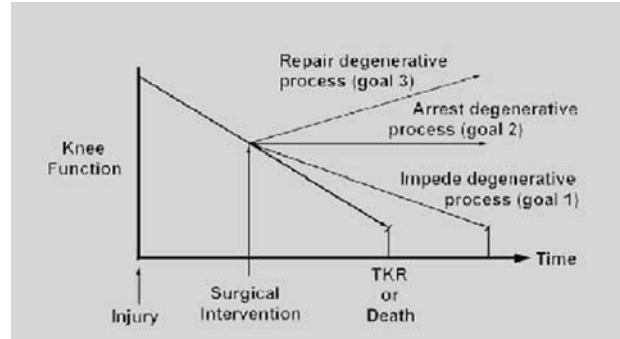


FIGURE 4. The primary goal of an ACL reconstruction in a degenerative knee is to impede the degenerative process, which would delay an impending TKR, hopefully negating its requirement. The secondary goal would be to arrest the degenerative process altogether, which may be possible in select cases. The third goal, while possibly not attainable with current techniques and technology, should still be a goal to which all outcomes are compared.

The primary goal will be to impede the degenerative process by stabilizing the ACL-deficient knee.

The secondary goal would be to arrest the degenerative processes and the tertiary goal would be to effectively repair the degenerative processes. Goal 3 may not yet be reasonably possible and goal 2 is limited by the combination of factors that vary by patient. However, achieving these goals has been partially possible through earlier intervention and by addressing the global condition in the knees of these patients.

During the surgical procedure when an ACL reconstruction is planned, attend to meniscal or chondral injuries in the appropriate manner and coordinate appropriate rehabilitation for concomitant injuries as they relate to each other. Osteophyte debridement and lysis of adhesions are usually required and may be time consuming. If resurfacing procedures, e.g., OATS or osteotomy, tibial tubercle transfer, meniscal transplant, or osteochondral transplant procedures, are required, they should be performed before or at least concurrently with other forms of intervention.

There are various potential surgical difficulties that may be encountered that include the presence of osteophytes, meniscal derangement, adhesions, synovitis, and loose bodies. Additionally, the patellofemoral joint may also be arthritic. Use of a tibial aimer that references tibial plateau bony anatomy may require clearing access to the over-the-back position, just anterosuperior to the posterior cruciate ligament insertion. Tibial tunnel placement may be difficult without bony reference instrumentation.^{19,20} The ACL stump



FIGURE 5. Medial and lateral notchplasty: in chronic ACL insufficiency, the notch is frequently obliterated by osteophytes

in revision cases is an unreliable anatomic landmark. Meniscal landmarks used for tibial tunnels are altered in DJD knees because previously resected or missing menisci are not unusual under these circumstances. Osteophytes tend to form juxtaposition to articular cartilage. Use of fluoroscopy may aid tibial tunnel placement under these conditions; however, familiarity with a fluoroscopy-validated soft-tissue reference method will improve success with its use.

Osteophytes may fill the intercondylar notch. The width of the notchplasty must be wide enough to preclude graft impingement. The presence of osteophytes may include significant formation on the medial wall of the intercondylar notch and require a medial notchplasty (Fig 5). While drilling the femoral tunnel through the tibial tunnel, the reamer shouldn't touch the walls. Osteophytes may also exist antero-posterior in the over-the-top position at the posterior aspect of the intercondylar notch. Femoral tunnel placement^{21,22} may be complicated by these posterior osteophytes. Care with osteophytes in this area prior to tunnel placement will ensure consistent accuracy of the femoral tunnel. Osteophytes may also obscure tibial plateau anatomy. The footprint technique (Fig 6) may be modified to a "double footprint" technique to prevent blowing out the back or placing the tunnel too far anterior without guide use.²⁸

Current Concepts: Allografts

Autografts are probably inappropriate for ACL-DJD reconstructions. Allograft tissue, bone-patellar tendon-bone (BPTB) or Achilles, significantly reduces postoperative surgical morbidity. Our early success with allograft use has led to expanded use of these grafts (Fig 7). The absence of harvest morbidity and its related pain allows patients to quickly begin ROM exercises, and if these patients progress to a

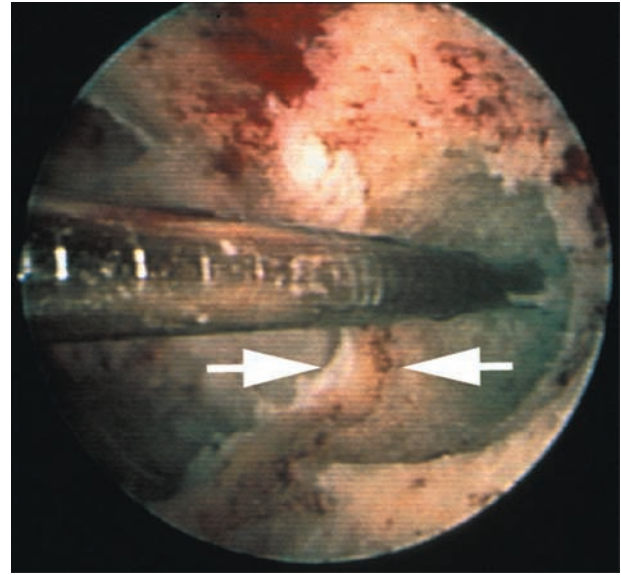


FIGURE 6. A posterior cortical margin of 1 to 2 mm indicates accurate anatomic placement. A second footprint will provide inspection of the posterior tunnel wall for bone and not osteophyte.

TKR we have not surgically altered the extension mechanism. Obviously, patients in pain do not move their knee as much as those patients whose pain is under control, and because stiffness is a concern and therefore early motion is important, we feel the reduced pain associated with allograft ACL reconstruction is a benefit.

Current Concepts: Bioabsorbable Fixation

Bioabsorbable fixation eliminates impediment to future surgery such as TKR.²³ Their clinical results have

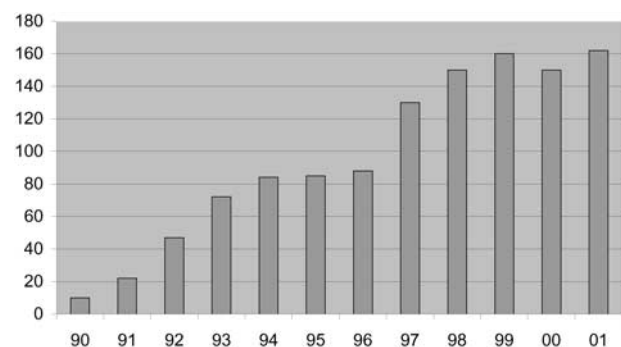


FIGURE 7. The X axis = years 1990 to 2001. The Y axis = number of ACL allograft cases. This graph shows a steady increase in the use of allografts over time subsequent to ongoing validation of their efficacy.

been shown to function equal to metal without the negative impact of metal.

Current Topics: Concomitant Injuries

A degenerative knee may have severe patellofemoral arthritis and require a lateral release. Patellofemoral joint arthritis sequelae may include extension deficit, staghorn osteophytes impinging on femur, an osteochondral defect from load shifting, and increased extension deficit. In addition to a general resection of patellofemoral osteophytes, debridement of the fat pad and generous notchplasty may permit regaining extension. These surgical details may allow the patient to walk on the tibiofemoral joint instead of the patellofemoral joint.

Severe anterolateral rotatory instability may be present and a lateral reconstruction may be required. Potential candidates include patients with failed ACL reconstruction without evidence of improper tunnel placement, improper graft fixation, or inappropriate rehabilitation. Additional candidates include patients who have had a previous lateral reconstruction in conjunction with and ACL reconstruction and are persistently unstable. A third group of potential candidates include those with a knee dislocation.

Studies

Shelboume and Wilckens¹⁶ reviewed results of a series of ACL-reconstruction patients with symptomatic arthrosis (average age, 29.5 years) with BPTB autograft reconstruction. Pain, stability, and activity level scores were all improved. Noyes and Barber-Westin¹⁵ reviewed results of a series of ACL-reconstruction patients with symptomatic arthrosis (average age, 29 years) with BPTB allograft reconstruction. Normal range of motion was restored. Pain and giving way symptoms were improved.

McGuire and Wolchok²⁴ reviewed a series of middle-aged ACL-reconstruction patients with symptomatic arthritis. There were 12 patients with an average age 47 years at surgery. Pain, giving way, and function were all improved.²⁵ Average ROM was improved. To date none of these patients has progressed to a TKR.

Conclusions

An ACL reconstruction in those patients with symptomatic DJD can reduce pain and improve activity level. ACL reconstruction provides another option to those patients whose only options were TKR or significantly reduced activity. It is still unclear whether

ACL reconstruction in these patients slows the degenerative process.^{15,26,27} The greater the degree of lateral rotary instability and the more evidence of a compromise of the lateral supporting structures, the more likely it is that an "isolated intra-articular ACL reconstruction" will fail.

The keys to success are to address all concomitant injuries, accurate tunnel placement, and rehabilitation that stresses ROM reacquisition and articular cartilage preservation. Equally important are the use of allograft to avoid the increased morbidity associated with autograft harvest, and bioabsorbable fixation, which eliminates metal-related impediments to future revisions and TKR if and when they become needed.

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SURGICAL TREATMENT OF ARTICULAR CARTILAGE INJURY

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With the limited potential of articular cartilage to heal even minor insult, numerous ways to treat articular cartilage injury have been investigated.^{1,2} Unfortunately, because of its highly organized, complex structure and function, the ideal method has yet to be found.^{3,4} Even before deciding a method of treatment, one is faced with the difficult task of making the correct diagnosis of a chondral injury and determining when a lesion needs treatment. The presenting symptoms may range from localized pain with catching, mimicking a meniscal tear, to vague aching. Physical findings are also varied ranging from slight effusion found to an obvious loose body.

Plain radiographs should be obtained, as they are useful in making a diagnosis if a large lesion is found. However, if a defect does not extend to the subchondral bone, they are often found to be normal. Magnetic

resonance imaging scans have historically been of equivocal benefit, but with new scanners and current imaging techniques, the sensitivity and specificity has been improved to the range of 85 to 95%.⁵

Although a chondral injury may evoke symptoms, many are incidental findings during arthroscopy for other pathology. In one published series reviewing over 31,000 arthroscopies, the prevalence of chondral abnormalities was 63% with grade IV lesions in 20% of patients and 5% in those less than 40 years old.⁶

With many patients never seeking treatment and the natural history of many chondral injuries often unknown, opinion is mixed as to treating the asymptomatic lesion.⁷ Even when treating a symptomatic lesion, variables that need to be considered include the size and depth of the defect, age and activity of the patient, and the condition of the surrounding articular cartilage.⁸ Evaluation for other pathology including limb alignment, ligament instability, and meniscal integrity also warrants consideration.

Of the various surgical procedures, lavage and debridement are considered the first line of treatment for articular damage. Simple irrigation of the knee to remove debris has been reported to improve symptoms in 50 to 70% of cases. The addition of chondroplasty to remove unstable cartilage increases the rate of success.^{9,10} However, the benefits are typically only short-lived and based on studies most appropriate for those with degenerative lesions and not for isolated defects.

When faced with a full thickness articular defect, four general categories of resurfacing methods are currently available. These include bone marrow stimulating techniques, osteochondral autografts, transplantation of autologous cells (ACI), and osteochondral allografts.¹¹ As will be shown, each has a role when treating articular lesions and should not be considered mutually exclusive.

Bone marrow stimulating techniques encompass penetrating the subchondral bone plate to induce vascular mediated healing of a defect. The stem cells within the blood proliferate and differentiate to form a fibrocartilage reparative tissue. Abrasion, drilling, and microfracture are methods described to achieve this goal.¹²⁻¹⁵ Perforating into the cancellous bone to assure bleeding and provide a stable anchor are cited as the benefits of drilling and microfracture over abrasion (Fig 8). Proponents of microfracture cite ease of access to lesions and possible thermal necrosis as benefits over drilling.

Following surgery, the patient is typically treated with continuous passive motion and limited weight

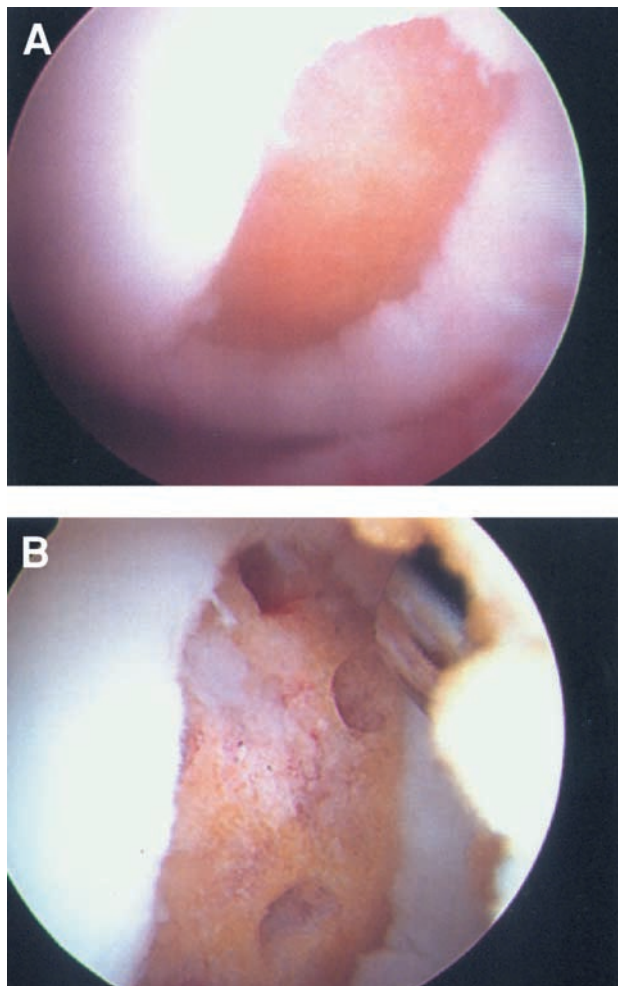


FIGURE 8. (A) A 1.5-cm medial femoral condyle defect debrided to subchondral bone. (B) Microfracture completed by perforating into cancellous bone.

bearing for 6 to 8 weeks in an effort to enhance the quality of tissue repair. Restriction of activities is often recommended until 6 months postoperatively.

The healing response is obviously dependent on the vascularity of the underlying bone and number of stem cells present, and therefore the younger patient typically has more predictable healing than one middle age or older. In addition, smaller lesions and those treated acutely are other variables that improve outcome. Contraindications to this method are defects secondary to avascular necrosis and those with subchondral bone loss.

Reports of the success of marrow stimulating techniques are varied. Some authors state the majority of patients treated with microfracture have a successful outcome beyond 5 years and heal with “hyaline like

cartilage.”^{16,17} Others have found the results are similar to debridement.¹⁸

The consensus is that marrow-stimulating techniques result predominately in fibrocartilage and durability is of concern. However, the method is easy to perform, with limited cost and complications. In general, it is considered by most to be a reasonable first step in the management of defects less than a few centimeters.

The principle of osteochondral autograft treatment is to take a plug of osteochondral tissue with intact articular cartilage from a less weight bearing area of a joint to fill a defect in one of greater function (Fig 9).^{19,20} Various terms have been used for the procedure based on the proprietary equipment with OATS (osteochondral transfer system) and mosaicplasty most common.

The size of the cylindrical plugs varies from 4.5 to 10 mm depending on the system used and size of the defect. Larger plugs are commonly obtained from the lateral femoral condyle above the sulcus terminalis.²¹ The intercondylar area of a notchplasty during ACL reconstruction can be used for harvesting smaller grafts. After the grafts are obtained, they are implanted into the defect in an attempt to recreate normal joint function. The donor site is then left to fill with fibrocartilaginous tissue. Some authors advocate using multiple, small grafts with fibrocartilage filling the interstices to enable treatment of large lesions and limiting donor morbidity. Others promote using large grafts to have an uninterrupted hyaline surface.

The ideal patients to treat with osteochondral autografts have an isolated defect such as osteochondritis dissecans or a post-traumatic lesion. The procedure is not indicated for someone with generalized joint pathology as the donor tissue is limited in quantity and needs to be of high quality. The procedure is technically demanding, as the grafts must recreate the normal joint contour to be functional. If the grafts are left proud, micromotion between the plug and recipient site leads to poor bone incorporation; if countersunk, they serve little if any function.²²

Postoperative treatment is dependent on the size of the defect, technique used, and stability of the graft. Full range of motion is typically allowed in all cases. If a single plug is used with the defect completely filled in press-fit fashion, immediate weight bearing has been permitted. If multiple small plugs are used to treat a large lesion, then weight bearing is not permitted for 6 weeks. Progression of activities is largely based on radiographic evidence of healing with full activities at 3 to 6 months.

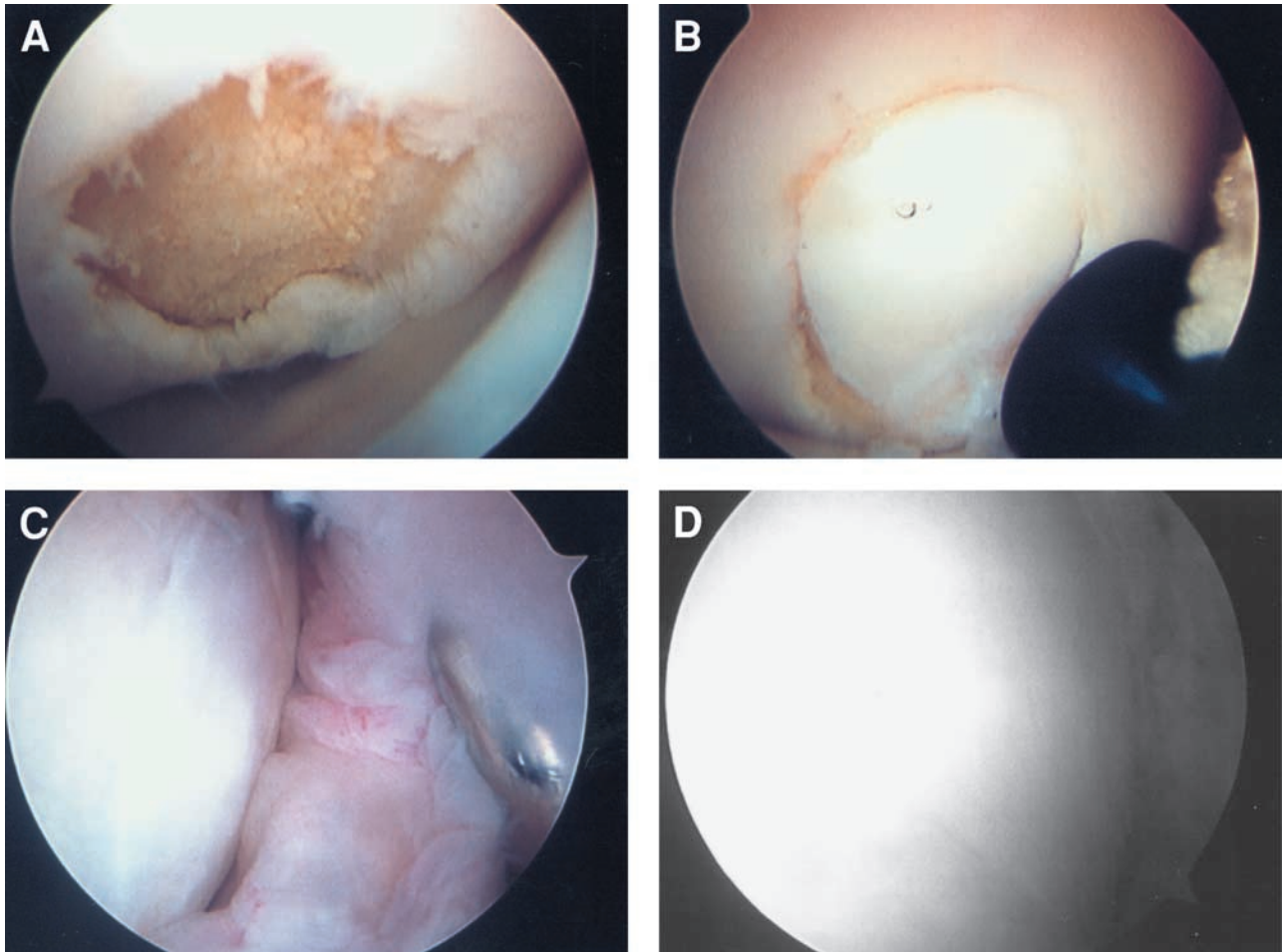


FIGURE 9. A 37-year-old female with a one centimeter defect of the medial femoral condyle treated with OATS procedure. (A) Defect before graft implantation. (B) Immediately after graft was implanted. (C) Defect 10 months after treatment. (D) Donor site 10 months after harvest.

Clinical studies have shown success rates of 80% to 90% when treating femoral condylar lesions, but many are with short-term follow-up of only a few years.^{20,23} Handgody et al. reported favorable results with mosaicplasty compared with marrow-stimulating techniques, with 87% good to excellent results at 5 years but only 34% with microfracture or drilling.²⁴

The main advantage of osteochondral autografts is the use of the patient's own fully formed articular cartilage containing viable chondrocytes. It also has the advantage of the ability to be done arthroscopically and is of limited cost. The disadvantages include that it is technically challenging, indications are limited, and longer follow-up is needed to answer the question of donor site morbidity.

With the early success shown with the procedure, some surgeons have expanded its use to treat defects

of several centimeters in size. At the current time, most authors recommend the use of osteochondral autografts as a secondary procedure for defects 2 to 2.5 cm or less, or possibly as a primary procedure for high demand patients.

ACI is an early-stage development of tissue engineering to treat articular injury.²⁵ It is a 2-stage procedure in which articular cartilage cells are arthroscopically harvested and expanded ex vivo in cell culture. The cultured chondrocytes are then implanted under an autologous periosteal tissue patch (Fig 10). The indications for the procedure are similar to osteochondral autografts except that ACI can be used to treat large lesions. The ideal candidates are in the age group of approximately 15 to 50 years and have unipolar defects secondary to trauma or osteochondritis dissecans.

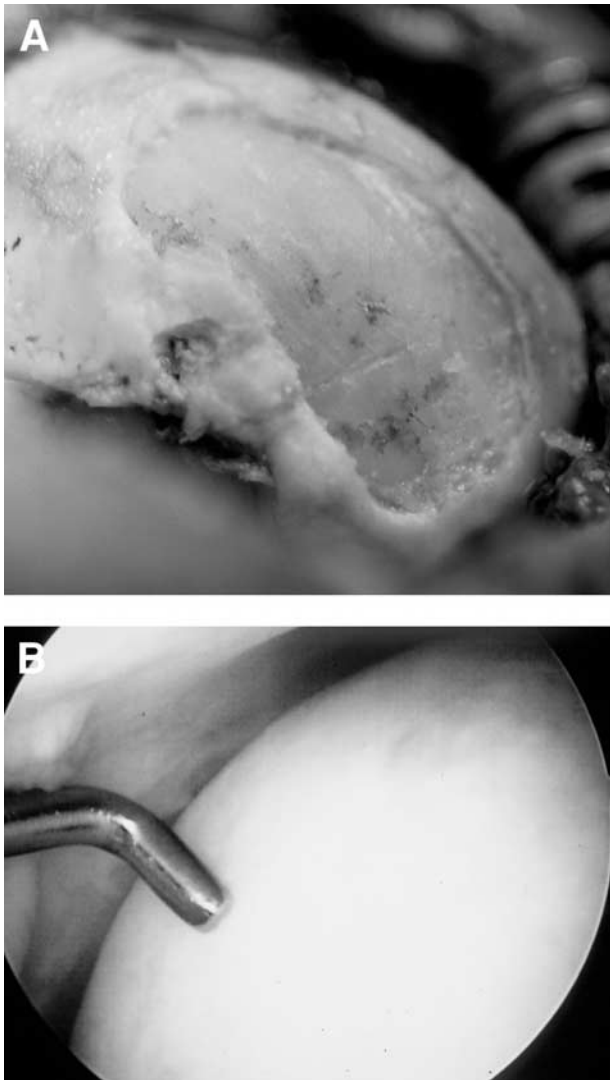


FIGURE 10. A 3-cm lesion of the medial femoral condyle. (A) Before ACI implantation. (B) Appearance 1 year postoperatively.

Rehabilitation is prolonged and the patient's ability to be compliant with the postoperative program needs to be considered when deciding treatment.²⁶ Toe touch weight bearing is recommended during the initial 6 weeks with gradual return to full weight bearing at 12 weeks. Low impact aerobic exercises such as jogging are restricted until 6 to 9 months and full activities not allowed until 12 months postoperatively.

The clinical outcome of multiple studies have reported good to excellent results typically in the range of 80% to 90% for femoral condylar defects with slightly lower success rates when treating patellofemoral lesions.²⁷⁻²⁹ Peterson et al. reported durability of the repair with 54 of 61 (84%) patients having a

successful outcome at 2 to 9 years of follow-up.²⁹ Histologic evaluation has shown the predominate repair tissue is hyaline-like. One study of 33 biopsies found hyaline-like tissue in 70% of cases with the remaining 30% having hyaline/fibrous or fibrocartilage tissue.

The advantage of ACI is the ability to treat large chondral lesions with a durable repair tissue. Disadvantages include the prolonged rehabilitation, the need for 2 procedures, and cost. In addition, the reoperation rate in most series is 5 to 10% due to arthrofibrosis and hypertrophy of the repair tissue. Although some surgeons have recommended the use of ACI for lesions as small as 1 cm, there is general agreement that the procedure is more appropriate for defects 2 cm or greater. In the low demand patient, it should be considered a secondary procedure. However, many surgeons have used it as a primary form of treatment in the high demand patient.

Osteochondral allografts for treating articular defects have the longest history of use, dating back several decades.³⁰⁻³² The principle is the same as osteochondral autografts in that bone with fully formed articular cartilage is transplanted to fill a defect (Fig 11).³³ Unlike autogenous tissue there is no risk of donor-site morbidity or limitations on size. However, as with any allograft tissue an immune response and disease transmission are a concern.³⁴⁻³⁶ Although sterilization methods would limit these risks, viable chondrocytes are needed for graft success and thus the grafts need to be fresh rather than fresh-frozen or cryopreserved. While the grafts were initially implanted within a few days after procurement, current techniques maintain structural function and viability of the majority of chondrocytes at 4 weeks.

Studies have shown the allograft is capable of an immune response and warrants concern. While most series report that the immunologic response is of little clinical significance, the procedure is contraindicated in patients with inflammatory arthropathies such as gout and rheumatoid arthritis.³⁷

After the patient is found to be a candidate, with the indications again similar to autogenous grafts but of larger size defects, the initial step is to obtain a graft that matches the size and contour of the defect. The grafts can also be of cylindrical form if the defect is well circumscribed. Dowel grafts of up to 35 mm can be prepared and have the benefit of often being press-fit. In larger lesions shell grafts are used and have the advantage of not being limited by size or shape, but require supplemental fixation. Postoperatively, the patients are kept non-weight bearing typically for 6 weeks for dowel grafts and as long as 12 weeks for

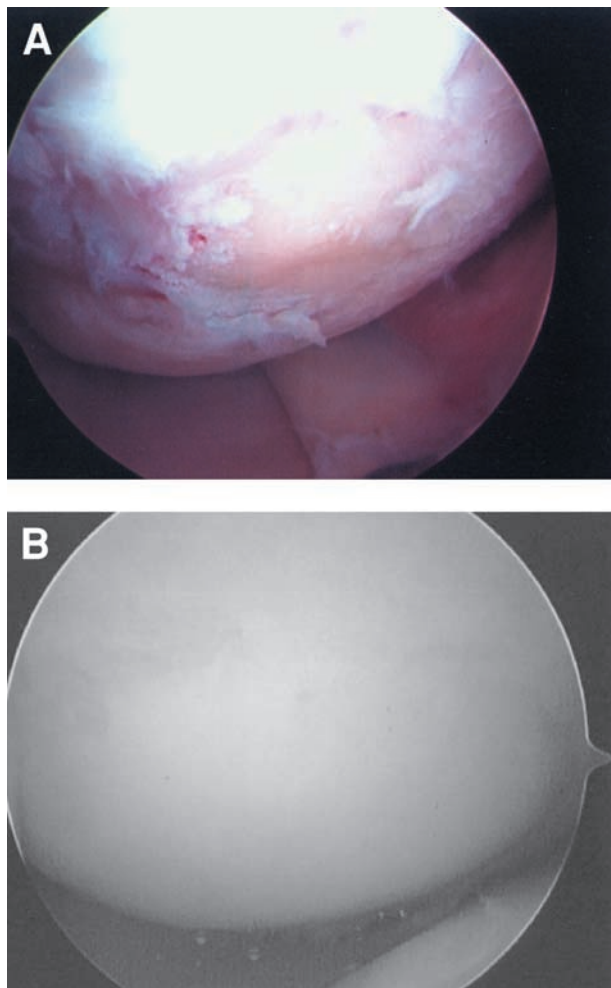


FIGURE 11. A 2.5-cm defect of the medial femoral condyle treated with an osteochondral allograft. (A) Defect before graft placement. (B) Graft at 5 months.

large shell grafts of the tibia. Full return of activities is routinely 6 months for femoral grafts and up to 12 months for tibial grafts.

Although the indications are narrow, the clinical follow-up is the longest of the procedures discussed. The University of Toronto reported 108 of 126 knees (86%) with good to excellent results for femoral defects secondary to trauma or osteochondritis dissecans.³⁸ The average follow-up for the group was 7.5 years (range, 2 to 22 years) with a survival of 95% at 5 years, 71% at 10 years, and 66% at 20 years. In another series of 211 knees with a mean follow-up of 52 months (range, 12 to 186 months), good to excellent results were reported in 116 of 125 (93%) of femoral grafts, 26 of 40 (65%) tibial grafts, and 35 of 46 (76%) patellofemoral grafts.³⁹

The advantage of osteochondral allografts is the ability to treat large lesions with a favorable outcome even at long-term follow-up and the treatment of choice for massive lesions. However, concern of disease transmission, immune response, limited availability, and cost have resulted in it being recommended for treatment of lesions only over 2 cm.

Emerging technologies, such as gene therapy and advancement of tissue engineering, give us great hope for the future in treating articular injuries not only of isolated defects, but also diffuse joint pathology.⁴⁰⁻⁴² While benefit has been found in animal studies with some of these advanced methods, clinical studies are in the early planning stages. However, many questions need to be answered before widespread use is available. Until then, the techniques described are considered the standard of care with each having a role when faced with articular cartilage pathology.

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CURRENT STATUS OF MENISCAL ALLOGRAFTS

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It is well documented that loss of a meniscus is extremely detrimental to the knee. Swelling and pain over the meniscectomized compartment are frequent early symptoms. Combined with ligament injury, the loss of a meniscus adds to the degree of instability. The final result is frequently end stage arthrosis. Advances in meniscus repair techniques have decreased the incidence of total meniscectomy but it still remains as one of the most common surgical procedures performed. New techniques of meniscus augmentation and regeneration with the use of growth factors and tissue scaffolds are promising but remain experimental at this time. The only technique able to replace a meniscus today is the use of a meniscal allograft.

Basic Science

Several characteristics of the meniscus facilitate its transplantation. The capsular vascular supply of the host induces peripheral healing of the meniscal allograft while cellular repopulation and nutrition is provided by joint fluid. The meniscus can be preserved by cryopreservation or fresh freezing. It can be stored for several years and used on demand.

Allograft Sterilization

The most common method used to insure a sterile graft is sterile harvest and procurement. Most tissue banks add low-dose radiation (less than 2.5 Mrad), which is effective in killing surface bacteria but is ineffective against spores and viruses like the human immunodeficiency virus.

History

The first published report of successful meniscus transplantation with an allograft was by Garrett and Stevenson.¹ Results were good with decreased pain in patients at follow-up. Studies by Carter,² Goble and Wilcox,³ and Shelton and Dukes⁴ have shown consistent healing of the meniscus and good pain relief. Tears of the posterior horn of the medial meniscus and shrinkage of the allograft have been reported. Biopsies show viable cells throughout the transplanted meniscus, but hypocellularity in the posterior horn of the medial meniscus is a constant finding. Noyes⁵ reported poor results using irradiated grafts in arthritic knees.

The majority of meniscus allografts have been cryopreserved and have been supplied by CryoLife, Inc (Kennesaw, GA). From 1989 through 2001, 465 different surgeons implanted 3,410 of their meniscus allografts. Initially, most were medial allografts but over the past 6 years almost 40% of meniscus allografts have been lateral.

Indications for Meniscus Allograft

Patient evaluation for meniscus allograft is extremely important. He or she should be an active individual under the age of 45 years. Limb alignment must be normal with no varus or valgus deformity. Degenerative changes should be minimal. Abrasive articular surfaces have been shown to abrade the meniscus allograft and tears are common in degenerative joints. Articular cartilage grades of Outerbridge II or better and radiographic grades of Fairbanks II or better are desirable.

Surgical Technique

Menisci were first implanted without bone anchors. Technically, this technique is less demanding, but without a firm anchor at each horn peripheral extrusion is a problem. The use of bone anchors to prevent extrusion is now recommended. Two bone plugs are used to anchor the medial meniscus by placing them in tunnels at the anatomic attachment of the anterior and posterior horns. The lateral meniscus can be inserted either by the plug anchor technique through drill holes or the slot or keyhole technique through a trough. The latter is more popular and maintains the correct anatomical distance between the 2 horns. Insertion of the grafts is aided by arthroscopic control through a small anterior arthrotomy. The meniscus is fixed peripherally with multiple interrupted sutures similar to a repair of a bucket handle tear.

Early crutch-assisted weight bearing and a full range of motion are permitted immediately postoperatively. No squatting or twisting maneuvers are allowed. Crutches are discontinued at 6 weeks, running permitted at 12 weeks, and normal activities resumed at 6 months. The replacement of a meniscus should be considered a salvage operation and extreme sports involving squats, cutting, and jumping discouraged.

Results

CryoLife collected an evaluation of their meniscal allografts done by 13 surgeons on 135 patients; 97 were medial implants and 48 were lateral. All were implanted using bone plugs as anchors. The patients' mean age was 35 years (range, 17 to 58 years). Mean follow-up was 5.1 years (range, 36 to 96 months). There were 93 male and 43 female patients. At follow-up, 86% of menisci were intact and considered successful. Failure was defined as partial or total removal of the graft. Six total meniscectomies and 14 partial meniscectomies comprised the failure group; 85% of the patients in this study had Fairbanks changes of grade III and IV classification of their articular cartilage. Despite this, 80% of patients rated their knees as normal to nearly normal and relief of pain was the most common reported benefit of the surgery.

Contraindications to Meniscus Allografts

Contraindications for meniscus allografts are rheumatoid arthritis, metabolic degenerative diseases such as gout, obesity, malalignment, and infectious disease. Patients with arthritic knees are at high risk of failure.

Summary

Following total meniscectomy, patients will often exhibit significant problems including pain, swelling, and increased instability. End-stage arthrosis is a predictable outcome. The only proven solution to this problem at this point in time is a meniscus replacement with an allograft. Meniscal allografts do carry risk of infection and disease transmission. Results at 5-year follow-up have been shown to be 80% to 85% successful. Posterior horn tears of the medial meniscus are the most common cause of failure. Pain relief has been the most consistent benefit. Further long-term studies are needed to determine if a meniscus allograft will prevent articular wear and end stage arthritis.

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