Degenerative Arthritis of the Knee in Active Patients: Evaluation and Management

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Abstract

The natural history and treatment of degenerative arthritis of the knee in active patients is a topic of great interest, with continually evolving concepts and techniques. Osteoarthritis is a spectrum of clinical entities, ranging from focal chondral defects to established arthrosis resulting from biologic and biomechanical hyaline cartilage failure. Evaluation of the active patient with knee arthritis should include a comprehensive history emphasizing symptom manifestation, activity level, and previous surgical treatment. The physical examination must include an evaluation of extremity alignment, gait patterns, and coexisting disorders of the spine and adjacent joints. Diagnostic testing is usually straightforward and should include the 45-degree flexion weight-bearing posteroanterior plain radiograph. Nonsurgical treatment modalities include rehabilitation, lifestyle modification, bracing, supportive devices, and medical management, including use of the new chondroprotective oral and injectable agents. Several surgical options exist, each with specific indications. Arthroscopic debridement can provide a positive, but often short-lived, reduction in the severity of symptoms. Tibial or femoral osteotomy may maintain the patient's active lifestyle and delay the need for arthroplasty. Unicompartmental and total knee arthroplasty can each provide reliable relief of symptoms but may not permit a return to the activities that the patient values.

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The natural history of progressive osteoarthritis following traumatic injury to the articular cartilage is well established in the orthopaedic literature.[1] Arthritis (more appropriately termed "arthrosis," because inflammation is not always present) is a common musculoskeletal condition. Primary osteoarthritis is more common than secondary. The etiology of osteoarthritis is unclear, but the process is a combination of qualitative biologic changes resulting in loss of biochemical homeostasis and subsequent biomechanical failure of the joint cartilage due to physical forces. Histologically, osteoarthritis is characterized by loss of integrity of articular cartilage, with diffuse fraying and fibrillation and hypertrophic changes in adjacent bone.

Primary osteoarthritis is a progressive "wear and tear" degenerative condition that increases in prevalence nonlinearly with age after 50 years. It is estimated that 25% to 30% of persons aged 45 to 64 years and more than 85% of individuals older than 65 years of age have radiographically detectable osteoarthritis.[2] At present, there are no data describing the relationship between premature arthrosis of the knee and patients' activity levels.[3]

Secondary osteoarthritis of the knee may occur much earlier, usually after significant injury resulting in either varus or valgus malalignment, intra-articular fracture, or ligamentous and meniscal deficiency.[4] In a study of 284 consecutive patients, Rangger et al[5] reported radiographically demonstrable increases in osteoarthritis after partial arthroscopic medial or lateral meniscectomy (38% and 24%, respectively) at an average follow-up of 53.5 months. The effect of focal articular damage on joint function and its role in the development of secondary osteoarthritis remain to be elucidated.[6] However, the progression of arthrosis seems to be exacerbated by meniscectomy.[7]

Articular cartilage disease is a spectrum of cartilaginous failure, ranging from symptomatic focal chondral defects to generalized arthrosis. The focus of this review will be on the management of established arthrosis, rather than the prevention of arthrosis or the indica-

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tions and techniques for cartilage restoration (previously reviewed in this journal by Buckwalter et al[1]).

Basic Science

Form and Function of Articular Cartilage

Hyaline cartilage provides the diarthrodial joint with a resilient, wear-resistant, low-friction surface with high compressive stiffness, effectively minimizing peak loads on subchondral bone. The ability of cartilage to facilitate normal synovial joint function depends on the mechanical properties, composition, and structural morphology of its extracellular matrix. When hyaline cartilage is damaged, the intrinsic repair process is limited.

Type II collagen fibers, which are highly cross-linked by type IX collagen fibers, are predominantly responsible for the structure of hyaline cartilage. Water is the largest constituent of articular cartilage, accounting for 70% to 80% of its total weight. Negatively charged hydrophilic proteoglycans or aggrecan molecules (20% to 40% of the dry weight) are composed of glycosaminoglycans attached to a linear core protein. A three-dimensional network of collagen fibrils and glycosaminoglycans imbibes water to a limited degree, creating a balance supportive of normal cartilage and joint function.[1] Chondrocytes (which constitute less than 10% of the dry weight) are embedded within this "composite gel" and produce the surrounding matrix and procollagen as a precursor to collagen. Minor collagens (e.g., types V, VI, and XI) are also present. Collagen provides cartilage with its strength and tensile stiffness. Proteoglycans provide elasticity and resilience.[1,8]

Biochemistry of Osteoarthritis

Matrix degradation is controlled, in part, by enzymes called metalloproteinases (e.g., collagenases, gelatinases, and stromelysin) secreted by chondrocytes. Cytokines, also produced by chondrocytes, enhance the osteoarthritic process. Primary osteoarthritis is signaled by an imbalance between the synthesis and degradation of the matrix components. Alternatively, mechanical destruction of cells and matrix due to blunt trauma may be the cause of secondary osteoarthritis.[1,8]

Independent of the cause of osteoarthritis, cartilage degeneration is associated with an increase in water content, a loss of glycosaminoglycans, and progressive intolerance to compressive joint force.[8] Inevitably, there is a reduction in tensile strength and resiliency. Despite the contribution of the synovial fluid in providing cartilage nutrition, a lack of intrinsic blood supply and a relatively high ratio of matrix to cellular components are responsible for the generally poor ability of cartilage to repair itself after mechanical disruption. The relative paucity of a local undifferentiated cell pool within cartilage and the low mitotic activity of chondrocytes make the healing of cartilage injury physiologically negligible. Although the essential histologic changes in osteoarthritis include degeneration of the joint cartilage, the subchondral bone also undergoes proliferative changes, including bone spur formation, cyst formation, and sclerosis.

The Meniscus and Osteoarthritis

Normally, the lateral meniscus carries about 70% of the lateral compartment load and the medial meniscus 50% of the medial compartment load with the knee fully extended.[9] The interrelationship between the loss of the load-bearing role of the meniscus after meniscectomy and the development of arthritis is well documented. Loads increase up to threefold in the involved compartment after minescectomy.[7,10,11] Not uncommonly, the young, previously active patient presents with disabling unicompartmental arthritis with progressive deformity following an injury and subsequent subtotal or total meniscectomy.

Classification

There is currently no reliable, generally accepted classification of osteoarthritis. Ideally, the description of osteoarthritis should include the size, depth, location, flexion-angle contact zone, and condition of the opposing articular surface. The Outerbridge classification system, initially developed for chondromalacia patellae, is often used to classify the degree of osteoarthritis, even though it does not incorporate all relevant factors. Grade 0 is normal articular cartilage. Grade I is characterized by softening and swelling of the articular cartilage. Grade II has early fissuring that does not reach the subchondral bone and is less than 0.5 inch in maximal diameter. Grade III shows fissuring that reaches the subchondral bone but is not exposed and has a diameter greater than 0.5 inch. Grade IV shows exposed subchondral bone of any diameter.

Evaluation

A complete history and a physical examination encompassing not only the involved extremity but also the spine, neurovascular system, and contiguous joints are imperative to avoid missing additional sources of knee symptoms. Inconsistent findings at the knee may indicate an alternative diagnosis, such as a primary disorder of the hip or back with referred pain to the knee (Fig. 1).

History

A comprehensive history focusing on the patient's employment, activity level, and symptoms is

A B

Fig. 1 Radiographs of a patient who complained of significant right knee pain, decreased range of motion of the right hip, and referred pain to the knee. **A,** Flexion weight-bearing radiograph of the knee demonstrates maintenance of normal and symmetrical joint spaces. **B,** Anteroposterior radiograph of the pelvis demonstrates high-grade arthrosis of the right hip.

important in determining the appropriate treatment option (Table 1). Patients with knee osteoarthritis commonly present with pain and/or functional limitations of varying severity and duration. Pain localized to one compartment of the knee is common early in the disease process, whereas in long-standing osteoarthritis, pain may be more diffuse.

Pain is typically activity-related and may be exacerbated by changes in barometric pressure. Rest pain is more common with advanced osteoarthritis or osteonecrosis. Difficulty with prolonged sitting, stair climbing, and squatting suggests patellofemoral involvement. Swelling related to a joint effusion or synovitis may be intermittent or constant. Mechanical symptoms of intermittent catching or locking may suggest gross articular surface irregularity, a loose osteochondral fragment, or a meniscal abnormality, which is commonly encountered in secondary osteoarthritis.

Instability and pain may both be present when ligamentous deficiency and arthrosis coexist. Instability due to pain, effusion, and subsequent quadriceps inhibition must be differentiated from instability due to ligamentous insufficiency, which may or may not be associated with pain. Prior responses to modalities such as physical therapy, change in body weight or activity, and need for assistive devices are important in determining the selection of therapy.

Physical Examination

A highly organized approach to the physical examination is critical. Assessment of body habitus and gait pattern is essential. An antalgic gait, with the knee flexed or in recurvatum, with a medial or lateral thrust, or with some other dynamic compensatory gait pattern (e.g., quadriceps avoidance or out-toeing) should be evaluated. Static limb alignment and deformity in the standing and supine positions serve as rough indicators of the duration and severity of the disease process. In cases of long-standing primary, posttraumatic, or postmeniscectomy secondary osteoarthritis, the presence of genu varum suggests medial-compartment involvement, and genu valgum suggests lateral-compartment involvement. True laxity may be anteroposterior, medial-lateral, or rotatory. Patients may exhibit pseudolaxity of the collateral ligaments on the side contralateral to the affected compartment when deformity is long-standing.

Range of motion is evaluated with side-to-side comparisons in the supine and prone positions. Patients commonly present with a mild flexion contracture (i.e., less than 10 degrees) and lack full flexion compared with the contralateral side. Larger losses of motion are unusual in active individuals. Patients may complain of swelling when in fact they perceive stiffness. Patellofemoral or joint-line crepitus is a common finding; the amount (mild, moderate, or severe) and type (fine or coarse) should be determined.

Patellofemoral evaluation includes patellar tilt, lateral and medial patellar glide, patellar facet tenderness, and stability in the coronal plane (i.e., varus or valgus at 0 and 20 degrees of flexion) and sagittal (anteroposterior) plane. Positive Lachman and pivot shift tests may indicate chronic anterior cruciate ligament insufficiency. Similarly, loss of the normal 5 to 10 mm of anteromedial tibial step-off relative to the medial femoral condyle or a positive tibial “sag sign” may be indicative of chronic posterior cruciate ligament insufficiency.

Evaluation for specific joint-line tenderness and swelling is essential. Provocative meniscal tests may be utilized. The back and ipsilateral hip and ankle should be evaluated for abnormalities, including decreased range of motion. The vascular status of the lower extremity must be carefully assessed and documented.

Table 1
Components of a Comprehensive History

- Location of symptoms
  - Isolated
    - Medial
    - Lateral
    - Patellofemoral
  - Diffuse
- Symptom type
  - Pain
  - Swelling
  - Decreased range of motion
  - Mechanical
    - Crepitus
    - Locking
    - Pseudolocking
    - Catching
  - Giving way
- Symptom timing
  - Onset
    - Sudden
    - Insidious
  - Duration
  - Exacerbating or ameliorating factors
- Symptom intervention and response
  - Lifestyle modification
  - Rehabilitation
  - Footwear
  - Assistive devices
  - Prior treatment
    - NSAIDs
    - Injections
    - Bracing
    - Rehabilitation
    - Surgery
- Past medical history
- Past surgical history
- Family history

Diagnostic Imaging

Reproducible radiographic examination is paramount for careful comparison of affected and unaffected knees (Table 2). A standing anteroposterior view with the patient’s body weight evenly distributed on both legs is commonly obtained. Alternatively, a 45-degree flexion weight-bearing posteroanterior radiograph[12] or a non-weight-bearing true 45-degree flexion lateral view and a 45-degree axial Merchant view of both patellae can be helpful.[13]

The 45-degree flexion weight-bearing posteroanterior radiograph may demonstrate subtle loss of joint space, especially in the lateral compartment, which is indicative of early chondrosis. Traditional extension views fail to show subtle joint-space loss (Fig. 2). Typically, the earliest loss of cartilage is in the 30- to 60-degree flexion zone and is thus easily overlooked on radiographs obtained in full extension. Because the 45-degree posteroanterior view provides a view of the notch, changes consistent with chronic anterior cruciate ligament deficiency, such as peaking of the tibial spines and narrowing of the intercondylar notch, are also evaluated. A variety of findings, including changes seen after meniscectomy (osteophyte formation along the periphery of the tibia, flattening of the femoral condyles, and joint-space narrowing), are more easily seen with this view.

Weight-bearing anteroposterior radiographs that include both extremities from the hips to the ankles most accurately reveal angular deformity and allow determination of the mechanical and anatomic axes of the limb. The mechanical axis is represented by a line connecting the center of the femoral head and the center of the tibiotalar joint and averages 1.2 degrees of varus (Fig. 3). With varus or valgus deformity, a line drawn between the center of the femoral head and the center of the ankle will fall medial or lateral to the center of the knee, respectively. The anatomic axis, which represents the longitudinal orientation of the femur with respect to the tibia, is formed by the intersection of the anatomic axes of the femoral and tibial shafts and averages 5 degrees of valgus in normal individuals.[14,15]

Magnetic resonance (MR) imaging is most useful in the setting of minimal radiographic change in

Table 2
Radiographic Findings

- Bone
  - Tibial or femoral osteophytes
  - Flattening of the femoral condyles
  - Subchondral sclerosis
  - Osteonecrosis
  - Osteochondritis dissecans
  - Notch narrowing
  - Peaked tibial spines
  - Loose bodies
  - Avulsion fracture
    - Segond fracture of lateral tibia
    - Pellegrini-Stieda lesion of medial collateral ligament at femoral insertion
- Cartilage
  - Joint-space narrowing
  - Chondrocalcinosis
  - Focal articular contour irregularities
- Soft tissue
  - Swelling
  - Atrophy
  - Effusion
  - Gas
  - Myositis ossificans
  - Ectopic calcification
- Alignment
  - Coronal-plane deformity (varus or valgus)
  - Sagittal-plane deformity
  - Patellar height
  - Patellar tilt or subluxation

Fig. 2 **A,** Method of obtaining a flexion weight-bearing radiograph so as to bring the weight-bearing portion of the femoral condyles into view and demonstrate subtle changes of joint-space narrowing. (Adapted with permission from Rosenberg TD, Paulos LE, Parker RD, Coward DB, Scott SM: The forty-five degree posteroanterior flexion weight-bearing radiograph of the knee. *J Bone Joint Surg Am* 1988;70:1479-1483.) Joint-space narrowing is not seen on a traditional anteroposterior extension weight-bearing radiograph **(B)**, but can be appreciated on a posteroanterior 45-degree flexion weight-bearing film **(C)**.

patients with localized pain and clinical findings consistent with a meniscal abnormality. This modality is also helpful in assessing patients with osteochondral fracture, osteonecrosis, or an isolated chondral defect. Degenerative meniscal tears often coexist with osteoarthritis; however, their presence may not correlate with typical symptoms. Proton-density, fat-suppression, and gradient-echo techniques are useful in evaluation of the articular cartilage.[16] In most cases, however, if joint-space narrowing is present on the 45-degree flexion weight-bearing view, MR imaging is not indicated.

Technetium-99m bone scans are helpful in difficult cases in which plain radiographs are normal despite a clinical scenario consistent with "arthritislike" symptoms.[17] For example, abnormal osseous activity detected on a bone scan (i.e., increased uptake in the patellofemoral compartment) may support a diagnosis of a periarticular lesion even when radiographs or MR images appear normal. Pretreatment and posttreatment evaluation for osseous homeostasis and workers' compensation assessments are other applications of scintigraphy.[17] Abnormal bone scans are likely in the presence of symptomatic osteoarthritis, meniscal tears, osteonecrosis, and osteochondral lesions. Diffuse uptake may be associated with reflex sympathetic dystrophy.

Treatment Options

The relatively slow progression of osteoarthritis permits treatment with use of a stepwise algorithm. Chronologic age is only a relative consideration, and physiologic age often more appropriately drives decision making. Nonsurgical treatment modalities include lifestyle modification, medical management, bracing, orthotics, and rehabilitation. Intolerable lifestyle changes or a poor response to nonoperative management may ultimately dictate surgical treatment.

Surgical modalities include joint arthroscopy and reconstructive procedures (osteotomy, arthroplasty) and may include preventive measures, such as meniscal transplantation and articular cartilage restoration (osteoarticular allografts and autografts, autologous chondrocyte implantation). Knowledge of the indications for each of these procedures is important in countering potentially unrealistic patient goals and expectations.

Nonsurgical Modalities

Lifestyle Modification

Patient education is of primary importance for lifestyle modification to be effective. Using high stools in lieu of prolonged standing, avoiding high-impact activities, and ensuring adequate rest may alleviate symptoms of activity-related pain and swelling. Obesity is a risk factor for osteoarthritis, and weight loss has been demonstrated to decrease the risk of developing and exacerbating osteoarthritis.[18] However, it is not realistic to expect patients to lose weight without providing education about alternative activities. Exercise that includes running and jumping should be avoided, but low-impact or nonimpact activities, such as swimming and bicycling, are excellent recommendations. Limiting squatting and stair climbing reduces pain in patients with significant patellofemoral arthrosis. Often,

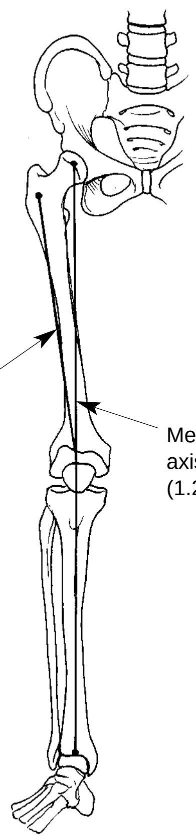


Fig. 3 The mechanical axis is a line drawn between the center of the femoral head and the center of the tibiotalar joint. It averages 1.2 degrees of varus relative to the center of gravity. The anatomic axis is formed by the intersection of lines drawn along the longitudinal axes of the femur and the tibia. It averages 5 degrees of valgus in normal individuals. (Adapted with permission from Hanssen AD, Chao EYS: High tibial osteotomy, in Fu FH, Harner CD, Vince KG (eds): *Knee Surgery*. Baltimore: Williams & Wilkins, 1994, p 1123.

patients can modify their employment responsibilities to those that are physically less demanding. Adaptations in the home, such as raising the level of a chair or toilet seat, may become necessary for those with chronic symptomatic osteoarthritis of the knee.

Rehabilitation

The need for referral to formal physical therapy depends on the severity of disease and the patient's goals. Progressive joint loading without applying directional impact loads or shear forces is important to prevent further disruption of joint integrity.[19] Range-of-motion exercises prevent or reduce contractures. Strengthening of the periarticular muscles helps to stabilize the knee, thereby relieving symptoms. Flexibility (especially of the hamstrings) and cross-training are important components of a complete rehabilitation program. Modalities such as heat, hydrotherapy, ultrasound, and cryotherapy are believed to work through reflex-mediated pathways involving free nerve endings, vasodilation, and other mechanisms. The duration and frequency should be adjusted to optimize the result and minimize symptoms.

Footwear

Energy-absorbing shoes or inserts may assist in reducing impact loads across the knee joint. Sole modification or use of off-the-shelf wedge inserts can correct pronation or supination deformities during weightbearing, leading indirectly to mechanical realignment. Decreasing loads across the painful compartment may reduce symptoms. For example, 0.25-inch soft wedges or 5-degree-wedged insoles placed medially or laterally will reduce lateral and medial joint reactive forces, respectively. Keating et al[20] found that more than 75% of 85 patients with medial-compartment osteoarthritis who were treated with a lateral wedged insole had statistically significant improvements in Hospital for Special Surgery pain scores at an average follow-up of 12 months. However, the efficacy of orthotic correction may be limited due to secondary correction at the level of the midfoot, ankle, or subtalar joints.

Bracing

Although knee sleeves do not alter knee alignment or joint reaction force, they may provide a sense of stability, possibly through enhanced proprioceptive feedback. Alternatively, patients with unicompartmental osteoarthritis can use an "unloader" brace. This device externally applies a three-point bending force, with one force applied at the center of the knee and two opposing forces applied proximal and distal to the knee joint, to reduce joint reactive forces in the involved compartment. An individual with a varus deformity can use a "valgus unloading" brace to decrease joint reactive forces on the medial side.

Horlick and Loomer[21] found significant improvement in their patients' pain and function with use of an unloader brace. In a prospective analysis of valgus bracing for medial-compartment arthrosis, Hewett et al[22] reported a 50% decrease in the number of patients complaining of pain with activities of daily living after brace wear for an average of 7 hours a day, 5 days a week.

Recently, Pollo[23] published a comprehensive review of the efficacy of bracing in the osteoarthritic knee. Limitations of bracing include the relative expense ($800 to $1,000) and the fact that braces are cumbersome and patients often elect not to use them on a daily basis. Bracing may offer a reasonable alternative for young patients and for patients who cannot undergo or wish to avoid osteotomy or knee arthroplasty.

Supportive Devices

The use of a cane in the hand contralateral to the affected limb is an effective way to relieve force and reduce symptoms due to osteoarthritis of the knee. A properly fitted cane should reach the top of the greater trochanter of a patient wearing shoes. A cane is especially useful during acute exacerbations in patients who have an antalgic gait due to pain and swelling of the knee. Unfortunately, patients are often reluctant to use these measures on a long-term basis because of perceptions of lost independence.

Pharmacologic Management

Medical management may include the administration of nonsteroidal anti-inflammatory drugs (NSAIDs), acetaminophen, and intra-articular corticosteroid injections. Some NSAIDs and corticosteroids decrease glycosaminoglycan synthesis and should, therefore, be used judiciously.[24] Injectable viscosupplementation and chondroprotective oral supplements may counter the osteoarthritis process by encouraging matrix and synovial fluid normalization.

Acetaminophen

The relationship between pain and inflammation in osteoarthritis is tenuous, but patients often view pain relief as the most important goal of their therapy, especially those with minimal effusions or swelling. Thus, because of its favorable side-effect profile and equivalent efficacy in relief of pain,[25] acetaminophen has become accepted as a first-line analgesic agent by the orthopaedic and rheumatologic communities. Use within recommended dose levels is rarely associated with renal toxicity or hepatotoxicity. The recommended dosage of acetaminophen is 650 mg every 4 to 6 hours as needed, to a maximum dosage of 4,000 mg per day. A dose of 1,000 mg three or four times daily is usually sufficient.

Nonsteroidal Anti-inflammatory Drugs

The anti-inflammatory and analgesic actions of NSAIDs make them the preferred pharmacologic agent for the swollen and painful arthritic knee. There are more than two dozen on the market, with no definitive studies demonstrating superior efficacy of one over another.[26] In general, they act by reversibly inhibiting the cyclo-oxygenase or lipo-oxygenase side of arachidonic acid metabolism, effectively blocking the production of proinflammatory agents, such as prostaglandins and leukotrienes. Also inhibited, however, are the beneficial effects of prostaglandins, such as the protective effects on the gastric mucosal lining (due to inhibition of gastric acid and pepsin secretion), renal blood flow, and sodium balance. Unlike the situation with aspirin, which has an irreversible antiplatelet effect that persists for the life of the platelet (i.e., 10 to 12 days), bleeding times usually correct within 24 hours after discontinuation of NSAIDs. These agents are predominantly eliminated by hepatic biotransformation and are then excreted renally.

Dyspepsia is the most common side effect. Other potential side effects include gastrointestinal ulceration, renal toxicity, hepatotoxicity, and cardiac failure. Most side effects are dose-related and are more severe in elderly individuals, with prolonged elimination. Contraindications include a history of gastrointestinal disease, renal disease, hepatic disease, or simultaneous anticoagulation therapy.[27] The American College of Rheumatology recommends that, in general, prolonged use should be monitored with an annual complete blood cell count, as well as liver function and creatinine testing as required. Hemograms and fecal occult blood testing are recommended before initiating NSAID therapy and regularly thereafter, depending on the risk.

Chondroprotective Oral Supplements

Glucosamine and chondroitin sulfate are endogenous molecules in articular cartilage with synergistic actions when taken together. Glucosamine is thought to stimulate chondrocyte and synoviocyte metabolism, and chondroitin sulfate is believed to inhibit degradative enzymes and prevent formation of fibrin thrombi in periarticular tissues.[28] Both agents have demonstrated tropism to synovial fluid and cartilage.

Exogenous glucosamine provides the body with raw materials for matrix production normally produced by chondrocytes from glucose metabolism. When administered orally as a salt, approximately 87% of the administered dose is absorbed in the gut and primarily processed through renal excretion, with lesser amounts processed by hepatic pathways.[29] The findings from randomized, double-blinded, placebo-controlled clinical trials suggest that glucosamine salts are efficacious in the management of osteoarthritis without any toxicity or side effects.[30]

Chondroitin sulfate, a glycosaminoglycan in articular cartilage, is important in binding collagen fibrils. Its protective effects are due to competitive inhibition of the degradative enzymes that lead to cartilage breakdown. Chondroitin sulfate is also an effective inhibitor of thrombus formation, which can occur in the periarticular tissues and limit subchondral and synovial blood flow.

Chondroitin sulfate is administered orally, and approximately 70% of the administered dose is absorbed in the gut. The average cost is approximately $50 per month. Clinical studies demonstrate effective pain relief and increased function without toxicity or side effects.[31] Randomized double-blind clinical trials are currently underway. A minimum of 1 g of glucosamine per day and 1,200 mg of chondroitin sulfate per day are the standard recommended dosages. Concurrent use seems to result in a net increase in the amount of normal cartilage matrix, potentially slowing the progression of osteoarthritis.

Corticosteroid Injection

Intra-articular injection of corticosteroid is helpful in patients in whom first-line anti-inflammatory therapy has failed or who have contraindications to use of acetaminophen or NSAIDs.[32] Indications include persistent inflammation and pain with a diagnosis of osteoarthritis unresponsive to other nonsurgical modalities for a period of 6 to 8 weeks. Intra-articular corticosteroids are potent anti-inflammatory agents with a minimal risk of systemic side effects or complications. Microcrystalline preparations (e.g., triamcinolone hexacetonide) offer the advantages of slower absorption and prolonged effect compared with more soluble preparations (e.g., betamethasone sodium phosphate). Crystalline corticosteroids can induce a corticosteroid-crystal synovitis or poststeroid flare, but this is relatively rare and usually self-limited.

Aspiration is not typically performed unless a tense effusion is present. An injection will provide variable relief, lasting from a few days to 6 months or more, especially in the absence of mechanical symptoms. Steroid injections should be limited to a maximum of three or four per year, as they usually become less effective with each successive injection. Complications include subcutaneous fat atrophy and skin pigmentation changes. Contraindications include recent fracture or macrotrauma and a suspected septic joint.

Viscosupplementation

Injectable hyaluronate therapy, or "viscosupplementation," is now available to treat osteoarthritis. At the time of this review, the Food and Drug Administration has approved two agents, Hyalgan (Sanofi Pharmaceuticals, New York) and Synvisc (Wyeth-Ayerst, Philadelphia) for the treatment of symptomatic osteoarthritis. Series of three and five weekly injections, respectively, are used. These high-molecular-weight solutions supplement the reduced concentrations of hyaluronate found in patients with osteoarthritis. With improved elastoviscosity, the synovial fluid is more effective in absorbing joint loads and lubricating articular surfaces. Additional benefits of hyaluronate therapy may include enhanced endogenous hyaluronic acid synthesis by type A synovial cells, proteoglycan synthesis by chondrocytes, anti-inflammatory effects, and analgesic effects on nociceptive pain receptors.[33] Depending on the severity of osteoarthritis, relief of pain may last from 0 to 6 months.[34] Like corticosteroid injections, hyaluronate therapy is likely to provide a bridge to more definitive treatment once osteoarthritis becomes symptomatic.

Aspiration is recommended before injection if there is effusion. Injections are not combined with a local anesthetic other than infiltration into the skin for the purpose of local anesthesia. After injection, patients should avoid strenuous or prolonged weight-bearing activities for 48 hours. Complications include hypersensitivity to hyaluronic acid preparations and severe postinjection inflammation (incidence of at least 1% for the latter). Injections are contraindicated for patients who have a known hypersensitivity to hyaluronate preparations and for those with skin diseases or infections in the area of injection.

Currently, the cost of these agents ranges between $500 and $1,500 for a series of three to five injections. There are a limited number of retrospective studies documenting the efficacy of viscosupplementation,[33,34] but ongoing prospective studies will ultimately determine the utility of these symptom-modifying agents with respect to their increased cost relative to corticosteroid injections and other conventional nonsurgical measures.

Surgical Modalities

Arthroscopy

In osteoarthritis, degenerating articular cartilage and synovium release pro-inflammatory cytokines (e.g., interleukin-1, tumor necrosis factor-α, and transforming growth factor-β). These cytokines induce chondrocytes to release lytic enzymes, leading to type II collagen and proteoglycan degradation. Arthroscopic lavage and debridement may wash out or dilute these inflammatory mediators.[35] Livesley et al[36] compared the results in 37 painful arthritic knees treated with lavage by one surgeon with those in 24 knees treated with physical therapy alone by a second surgeon and suggested that there was better pain relief in the lavage group at 1 year. Edelson et al[37] reported that lavage alone had good or excellent results in 86% of their patients at 1 year and in 81% at 2 years using the Hospital for Special Surgery scale.

Jackson and Rouse[38] reported on the results of arthroscopic lavage alone versus lavage combined with debridement with 3-year follow-up. Of the 65 patients treated with lavage alone, 80% had initial improvement, but only 45% maintained improvement at follow-up. Of the 137 patients treated with lavage plus debridement, 88% showed initial improvement, and 68% maintained improvement at follow-up. Gibson et al[39] demonstrated no statistically significant improvement with either method, even in the short-term. Patients who present with flexion deformities associated with pain or discomfort and osteophyte formation around the tibial spines may benefit from osteophyte removal and notchplasty, as demonstrated by Puddu et al.[40]

The efficacy of lavage with or without debridement is controversial, and randomized prospective controlled trials have not been performed. The literature suggests that arthroscopic lavage and debridement, when performed for appropriate indications, will provide improvement in pain relief for 50% to 70% of patients, lasting from several months to several years.[41-43] Drilling and abrasion arthroplasty do not appear to offer additional benefit.[44] Arthroscopy is also a sensitive way to evaluate cartilage when contemplating osteotomy or unicompartmental knee arthroplasty, as plain radiography and MR imaging often underestimate the extent of osteoarthritis.[45]

Several factors determine prognosis after lavage and debridement (Table 3). Those who benefit most present with a history of mechanical symptoms, symptoms of short duration (<6 months), normal alignment, and only mild to moderate radiographic evidence of osteoarthritis.[41-43] It is not uncommon for patients to have unrealistic expectations after arthroscopic debridement. Thus, it is important to counsel patients about the limited indications and palliative results.

Two vertically placed parapatellar tendon portals are useful when performing arthroscopic debridement and/or meniscectomy. A three-port sheath accommodating pressure, inflow, and outflow from a pump obviates the need to place a superomedial or superolateral outflow portal, which would potentially slow postoperative rehabilitation due to painful quadriceps muscle inhibition.

This procedure should be kept as simple as possible, with the goal being only to remove unstable meniscal flaps. Clinically irrelevant osteophytes are not debrided. One should avoid prolonged surgical time and limit surgery to only the involved compartment. Unstable meniscal tears are contoured to a stable rim, leaving a maximum of normal tissue. Only loose or unstable chondral flaps are removed to improve the transition between normal and abnormal cartilage. Overzealous use of motorized instruments can damage both normal and abnormal but biomechanically sound cartilage surfaces. Articular lesions should not be curettaged, abraded, or drilled unless a femoral perioperative marrow-stimulating technique protocol is followed.

Osteotomy

General indications for osteotomy include varus alignment with medial-compartment arthrosis and valgus alignment with lateral-compartment arthrosis in relatively young and/or obese patients. A trial of an offset short-leg walking cast (Fig. 4) to “off-load” the affected compartment, using medially placed (for valgus deformity) or laterally placed (for varus deformity) contact points,[46] is especially useful for patients in whom there is uncertainty about the status of the contralateral tibiofemoral compartment or coexisting patellofemoral arthrosis. Patients are asked to walk with the corrective cast in place for 3 days and are then questioned about the effects on pain reduction during ambulation.

Medial-Compartment Arthrosis

In the younger active patient with varus malalignment and medial arthrosis, a valgus-producing high tibial osteotomy decreases medial-compartment loads, dimin-

Table 3
Prognostic Factors for Arthroscopic Debridement

Prognosis	History	Physical Examination	Radiographic Findings	Arthroscopic Findings
Good	Short duration Associated trauma First arthroscopy Mechanical symptoms	Medial tenderness Effusion Normal alignment Ligaments stable	Unicompartmental Normal alignment Minimal Fairbank’s lesions Loose bodies Relevant osteophytes	Outerbridge I or II Meniscal flap tear Chondral fracture/flap Loose bodies Osteophyte at symptom site
Poor	Long duration Insidious onset Multiple procedures Rest pain Litigation Work-related	Lateral tenderness No effusion Malalignment Varus >10° Valgus >15° Ligaments unstable	Bi- or tricompartmental Malalignment Significant Fairbank’s lesions Irrelevant osteophytes	Outerbridge III or IV Degenerative meniscus Diffuse chondrosis Osteophyte away from symptom site

A B

Fig. 4 **A,** Preoperatively placed short-leg walking cast. **B,** A lateral extension flush with the bottom of the cast, extending from the level of the midfoot to the hindfoot, is fashioned to mimic the off-loading effects of a valgus-producing osteotomy for varus medial arthrosis.

ishes symptoms, and improves function. In general, it is better to perform the osteotomy early (when there is less than 5 degrees of varus) and to overcorrect by 2 to 3 degrees. Mild to moderate patellofemoral osteoarthritis is still compatible with a successful result following high tibial osteotomy.[47] Contraindications include panarthrosis, severe patellofemoral disease, severely restricted range of motion (extension loss of more than 15 to 20 degrees or flexion less than 90 degrees), instability, and inflammatory arthritis.

Coventry[48] determined that 61% of his patients had less pain and 65% had better function 10 years after high tibial osteotomy. In a prospective study of 41 patients, Noyes et al[49] noted that 88% were satisfied at a mean of 58 months postoperatively and would undergo the operation again. Nagel et al[50] concluded that activities that may be inappropriate after total knee arthroplasty (e.g., climbing, jumping, impact sports, and jogging) were possible for their patients after high tibial osteotomy.

Several fixation methods may be used for high tibial osteotomy. A variation of Coventry's technique[48] involves the use of two step-off staples through a 5-cm anteroinferior oblique incision extending from the anterior portion of the head of the fibula to just lateral to the tibial tubercle along Langer's lines. The degree of correction and the thickness of the laterally based wedge are based on measurements on long-cassette films and intraoperative measurements of the tibial plateau, as described by Port et al.[14] Laterally based buttress plates have recently become available. These devices offer the advantage of greater precision with the use of cutting jigs and rigid fixation applied under compression, allowing immediate weight bearing. Disadvantages include more extensive dissection and the potential need for plate removal.

Closing-wedge osteotomies have an inherent disadvantage in that the tibiofibular joint must be disrupted, and some degree of shortening is required. Additionally, revision to a total knee arthroplasty can be challenging because of difficulties in exposure and joint-line alterations. Alternative methods for the treatment of varus disease include the medial opening-wedge osteotomy. Fixation techniques include a medially based plate and rigid internal fixation. Disadvantages include the need for iliac-crest bone graft.

Deformities that are greater than 10 degrees or are associated with a varus thrust with lateral laxity can be treated by using medially based callotasis with a unilateral, uniplanar external fixator (Fig. 5). This technique allows precise postoperative angular correction, maintains bone stock, avoids disruption of the proximal tibiofibular joint, lengthens the tibia, and avoids the extensor mechanism, potentially permitting a less complicated conversion to a total knee replacement. Disadvantages include pin-tract infection, loss of correction, nonunion, and the inconvenience of wearing an external fixator for 12 weeks.

Lateral-Compartment Arthrosis

Lateral-compartment osteoarthritis associated with a valgus deformity is much less common than isolated medial-compartment osteoarthritis. Mild deformities (<10 degrees of valgus) can be treated with a medial high tibial closing-wedge osteotomy; more severe cases and deformities involving a lateral sloping joint line can be treated with a distal femoral osteotomy.[51] Contraindications include panarthrosis, severe patellofemoral disease, severely restricted range of motion, instability, and inflammatory arthritis.

The surgeon should avoid overcorrection and should strive to achieve a mechanical axis of 0 degrees and an anatomic axis of 6 to 7 degrees. Mild deformities of less than 10 degrees can be managed by using a medially based closing-wedge high tibial osteotomy with preservation of the medial collateral ligament. Valgus deformities of greater than 10 degrees are most commonly treated by distal femoral osteotomy to prevent joint-line obliquity, incomplete load transfer, and medial tibial subluxation following proximal tibial osteotomy.[52] Typically, a 90-degree-offset dynamic-compression bladeplate is inserted on the medial aspect of the distal femur parallel to the articular surface in an attempt to achieve a mechanical axis of approximately 0 degrees.[53]

Healy et al[54] have reported good or excellent results in more than 80% of patients after the treatment of valgus deformities. Finkelstein et al[51] determined that the probability of symptom relief after a distal femoral varus-producing osteotomy at 19 years was 64%. Others have reported similar results, but with shorter follow-up.[54] Following this procedure, activity levels are generally maintained but not significantly improved.

Fig. 5 External fixator in place after correction of a varus deformity greater than 10 degrees by means of medially based hemicallotasis.

Arthroplasty

For an active individual with moderate to severe arthritis who is older than 50 years and is willing to forgo high-impact activities, total knee arthroplasty is an excellent option. Postoperatively, patients should avoid impact loading, such as running, cutting, and pivoting. However, bicycling, swimming, golf, and walking are allowed without restriction.

Although earlier reports suggested that total knee arthroplasty in younger patients was predisposed to premature implant wear, loosening, and osteolysis, more recent studies have reported similar results for both younger and older patients. Gill et al[55] reported on the 5- to 18-year follow-up (mean, 10 years) of total knee arthroplasty in patients less than 55 years old. In that series, only 2 of 72 knees required revision, and function was rated as good or excellent in all knees on the Knee Society scale. Similar results have been reported by other authors.[56,57]

Unicompartmental knee replacement has a well-established role in the treatment of osteoarthritis limited to one compartment of the knee in selected patients.[58,59] Although osteotomy is preferred for young, active, and overweight patients, this procedure is a reasonable alternative for patients who are at least 60 years old, and may also be an option for younger patients with relatively normal alignment. Patient selection is critical, however, and the procedure requires technical precision. Laborers and recreational athletes are not candidates for this procedure unless they are willing to modify their activity levels.

Excellent results at 5- to 10-year follow-up have been reported.[58,59] Marmor[60] reported 70% satisfactory results at 10- to 13-year follow-up of 60 unicompartmental knee arthroplasties; 87% of patients had no significant pain. Failures in most series were attributed to improper patient selection or technical error. Revision to total knee arthroplasty, although technically demanding, is optimized when bone stock deficiency is minimal.

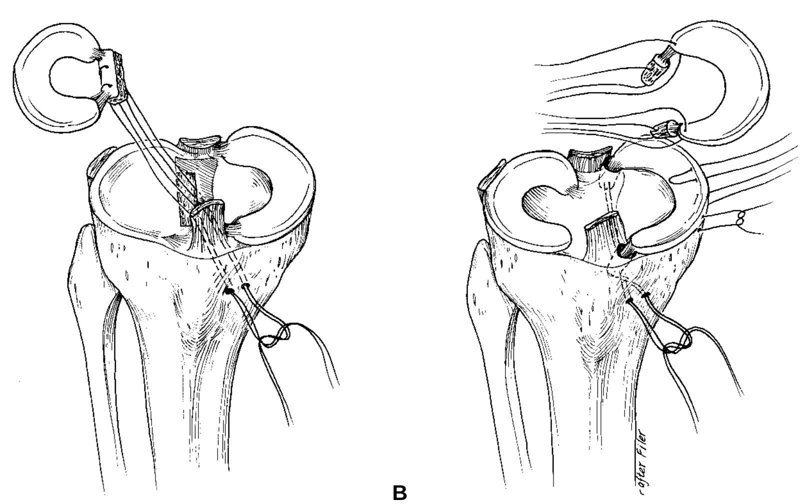
Contraindications include lack of technical expertise, panarthrosis, inflammatory arthritis, obesity, more than 10 degrees of varus deformity or 15 degrees of valgus deformity, a flexion arc of less than 90 degrees or a flexion contracture of more than 5 degrees, cruciate ligament insufficiency, significant loss of subchondral bone, and crystalline arthropathy. As is the case with osteotomy, mild to moderate patellofemoral disease does not preclude a successful result.

Future Directions

The natural history of the focal chondral defect in the meniscectomized knee has not been precisely delineated. Activity level, body habitus, alignment, ligamentous instability, and even genetics are important determinants of disease progression. In the symptomatic patient who has a deficient meniscus or discrete areas of cartilage loss, meniscus implantation or cartilage restoration may be the ideal means of preventing the progression of arthritis.

Since 1992, nearly 80 allograft meniscal transplantations have been performed at our institutions. Meniscus transplantation is indicated for patients with prior meniscectomy, persistent pain, intact cartilage or low-grade arthrosis (i.e., less than grade III), normal alignment, and a stable joint. Simultaneous or staged ligament reconstruction or realignment procedures are performed as indicated.

A cryopreserved or fresh-frozen meniscus is size-matched on the basis of measurements on plain radiographs, taking magnification into account. The procedure is typically performed with an arthroscopically assisted approach with use of a small arthrotomy to place the meniscus into the joint. The meniscus is anchored by either a bone block (laterally) or bone plugs (medially), and repair is performed with standard meniscal repair techniques (Fig. 6).



A B

Fig. 6 Placement of prepared meniscus allograft. **A,** Lateral meniscus based on a bone block maintains the close proximity of the anterior and posterior horns. **B,** Medial meniscus based on separate bone plugs.

Of our first 22 patients with a minimum 24-month follow-up, nearly half underwent anterior cruciate ligament reconstruction simultaneously. The overall knee rating on the University of Pittsburgh Knee Scale was 87 (range, 75 to 100). Self-reported overall function was normal or nearly normal in 21 of 22 cases and abnormal in 1 case. Cameron and Saha[61] reported the results in 63 patients; more than 85% had good or excellent results at a mean follow-up of 31 months. Other authors have reported comparable results over similar time periods.[62-64]

Articular cartilage implantation is indicated for patients with persistent pain and a focal area of cartilage loss due to trauma or osteochondritis dissecans in which the joint is otherwise preserved without degenerative arthritis. There are three main techniques with which to restore articular cartilage: autologous chondrocyte implantation, local transfer of osteochondral plugs, and use of allograft osteochondral implants. Small localized lesions (<2 cm^2) may be amenable to osteochondral autografting (also known as mosaic chondroplasty). To date, questions remain regarding the morbidity of the donor sites following autograft transplantation and the biomechanical consequences of the irregularities present between the plugs themselves. Larger areas that are discrete in size and location on the femoral condyles or trochlea may be treated with autologous chondrocyte implantation. Long-term results comparing this procedure with traditional techniques, such as microfracture, are in progress. Reconstruction with the use of osteochondral allografts has been reported when the articular cartilage and/or underlying bone was deficient. The results are dependent on patient selection and are optimized in unicompartmental and unipolar lesions.

Summary

Knee arthritis in the active individual compromises activities of daily living and participation in sports. Carefully prescribed treatment involving nonoperative modalities, such as medication, activity modification, physical therapy, and chondroprotective agents, is often successful but is only palliative in nature. Once symptomatic, osteoarthritis is usually progressive. Arthroscopy should be performed only with a clear understanding of the prognostic factors determining success and failure. Osteotomy of the tibia or femur is an excellent alternative when deformity and symptoms coexist, especially when performed early in the disease process. Total knee arthroplasty should be considered only when all other options have been exhausted and only with the patient's acknowledgment that a return to high-impact activities will not be possible. In selected cases, meniscus transplantation may prevent or delay the need for more definitive procedures, such as arthroplasty. Utilizing procedures that address the combination of meniscal and articular cartilage lesions in order to prevent progressive arthrosis is likely to become more commonplace as indications and results become better defined.

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