Arthroscopic Management of Osteoarthritis of the Knee

Stephen A. Hunt, MD, Laith M. Jazrawi, MD, and Orrin H. Sherman, MD

Abstract

Recent advances in instrumentation and a growing understanding of the pathophysiology of osteoarthritis have led to increased use of arthroscopy for the management of degenerative arthritis of the knee. Techniques include lavage and débridement, abrasion arthroplasty, subchondral penetration procedures (drilling and microfracture), and laser/thermal chondroplasty. In most patients, short-term symptomatic relief can be expected with arthroscopic lavage and débridement. Greater symptomatic relief and more persistent pain relief can be achieved in patients who have acute onset of pain, mechanical disturbances from cartilage or meniscal fragments, normal lower extremity alignment, and minimal radiographic evidence of degenerative disease. Arthroscopic chondroplasty techniques provide unpredictable results. Concerns include the durability of the fibrocartilage repair tissue in subchondral penetration procedures and thermal damage to subchondral bone and adjacent normal articular cartilage in laser/thermal chondroplasty. Although recent prospective, randomized, double-blinded studies have demonstrated that outcomes after arthroscopic lavage or débridement were no better than placebo procedure for knee osteoarthritis, controversy still exists. With proper selection, patients with early degenerative arthritis and mechanical symptoms of locking or catching can benefit from arthroscopic surgery.

J Am Acad Orthop Surg 2002;10:356-363

Since 1941, when Magnuson introduced the term joint débridement for the removal of hypertrophic synovial membrane, osteophytes, loose bodies, and diseased cartilage, the procedure has been used to attempt to relieve symptoms of degenerative arthritis of the knee. With the emergence of arthroscopy in the 1970s and advancement in techniques and instruments, investigators began to study the role of arthroscopy in the evaluation and treatment of degenerative joint disease. In 1990, Burks[1] described three indications for the use of arthroscopy in the treatment of osteoarthritis of the knee: to define pathology, treat focal lesions within the joint, and prolong the use of the knee with generalized treatment such as débridement and/or abrasion arthroplasty. Although techniques have changed, the goals of surgical treatment remain the same: to decrease or eliminate pain and improve function.[2]

However, controversy exists regarding the efficacy of arthroscopy for knee osteoarthritis. Limitations of short-term follow-up and a lack of well-defined, randomized control studies until recently made it difficult to define the role of this procedure in the degenerative knee.[3] Jackson et al[4] argued that arthroscopic lavage and débridement offer benefits to patients in the early stages of osteoarthritis through the washout and dilution of destructive enzymes in the synovial fluid. They claimed that patients who received this treatment had a better quality of life and used markedly less anti-inflammatory and analgesic medications. They believed that a grading system to classify patients based on radiologic findings could help select patients who would benefit most from the procedure. They also stated, however, that further examination of the effects of arthroscopic procedures in the degenerative knee were needed—particularly in the form of prospective, randomized, blinded studies—to evaluate the placebo effect of this technique. A recently published study[5] of this type suggested that there is no benefit in the use of knee arthroscopy for the management of arthritis. However, despite the results of this study, controversy still exists regarding the use of arthroscopy for the management of knee osteoarthritis.

Dr. Hunt is Resident, NYU–Hospital for Joint Diseases, New York, NY. Dr. Jazrawi is Assistant Professor, Department of Sports Medicine, NYU–Hospital for Joint Diseases. Dr. Sherman is Director, Department of Sports Medicine, NYU–Hospital for Joint Diseases, New York.

Reprint requests: Dr. Jazrawi, 301 East 17th Street, New York, NY 10003.

Treatment Modalities for the Osteoarthritic Knee

Arthroscopic Lavage and Débridement

During arthroscopic lavage, the joint is visualized and irrigated with normal saline or lactated Ringer's solution. Débridement procedures excise damaged portions of articular cartilage, meniscus, synovial membrane, or ligaments found within the joint (Fig. 1). The success of lavage and débridement has been attributed to a decrease in free particles and damaged portions of cartilage and meniscus that stimulate inflammation of the synovial tissue, cause joint effusions, increase the levels of proteolytic enzymes in the synovial fluid, and increase collagenolytic activity that causes friability of the articular cartilage.[6] Lavage alone dilutes the joint fluid, thereby decreasing the concentrations of degradative enzymes in the knee and consequently slowing the catabolism of proteoglycans and collagen, maintaining the integrity of the joint.[4] The removal of tissue debris during débridement improves symptoms by reducing the source of irritation of the synovial tissue.[6] Patients with mechanical disturbances caused by cartilage and meniscal fragments have demonstrated substantial improvement in function and symptoms when these fragments are removed by arthroscopic techniques.[7]

The efficacy of the lavage procedure may correlate with the extent of disease. In one study,[8] 37 osteoarthritic knees treated by arthroscopic lavage and physiotherapy were compared with a control group of 24 knees treated by physiotherapy alone. Those treated by lavage improved to a greater degree than did those in the control group. This improvement was maintained at 1-year follow-up. Additionally, the patients with mild radiographic osteoarthritic changes experienced more pain relief than did those with severe changes. Although the physiotherapy group noted some improvement in pain relief, these were short lived; by the end of 1 year, these patients had returned to their pretreatment condition. In one prospective review of arthroscopic débridement procedures, 75% of patients had either a good or excellent result.[9]

Although these techniques may temporarily improve patient symptoms, they cannot stop the disease process and often provide no benefit to patients with severe disease. Baumgaertner et al[10] studied the efficacy of débridement procedures on older (average age, 63 years; range, 51 to 76 years) arthritic patients who had had no success with other methods of nonsurgical treatment and maintained low activity levels. Only 52% of patients experienced benefit; 39% had no benefit; and 9% experienced only temporary improvement. Clearly, the severity of the disease has implications for the outcome of treatment.

Other studies have attempted to ascertain whether lavage or lavage plus débridement offered better relief for the osteoarthritic knee.[11-13] In 1986, Jackson et al[11] in a randomized study reported on 65 patients treated with lavage alone and 137 patients treated with lavage and débridement. Of the 65 who underwent lavage only, 80% showed initial improvement; however, this deteriorated to 45% at 3-year follow-up. For the 137 patients treated with lavage and débridement, 88% showed initial improvement; 68% maintained their improvement at 3-year follow-up.[12] In contrast to these findings, Gibson et al[13] found that patients had some functional improvement after lavage but not after débridement, and neither method significantly relieved symptoms. In addition, the authors concluded that while lavage may offer some short-term benefit in moderate osteoarthritis of the knee, débridement offered no benefits in such cases.

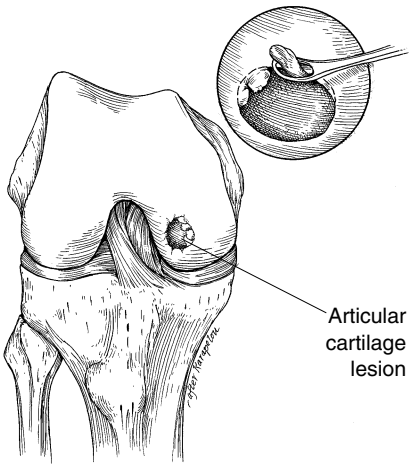

Figure 1 Débridement of a medial femoral condyle articular cartilage lesion to a stable rim using arthroscopic instrumentation (inset). (Adapted with permission from Miller MD: Atlas of chondral injury treatment. *Op Tech Orthop* 1997;7:289-293.)

Because of these marked differences in results, it is difficult to draw conclusions about the efficacy of these procedures.[14-17] Some suggest that aggressive removal of tissue may aggravate the patient's problem.[14] Others remain skeptical about the short-term and unpredictable improvement in symptoms despite the low risk-to-benefit ratio of the procedure.[16,17] Most commonly, studies report that some patients have maintained improvement, some show no improvement, and some are made worse by these techniques.[14,16,17] No consensus favors or opposes arthroscopic lavage and débridement techniques in treating osteoarthritis of the knee. However, patients with extensive loss of articular cartilage, malalignment, instability, restricted range of motion, and marked radiographic evidence of osteoarthritis seem to have a lower probability of experiencing any significant benefits from these techniques.[18] These conflicting reports may be explained by varia-

tions in entrance criteria, definition of procedure, and outcome measures,[19] as well as by the fact that most are retrospective studies.[10,16,20-23]

Closed-Joint Lavage

Several studies[24-26] have examined the effectiveness of closed-joint lavage using a 14-gauge needle in reducing symptoms and improving function. This technique washes out and dilutes the degradative enzymes and irritant particles in the joint space while avoiding the more extensive trauma caused by mechanical shavers. In one study,[24] 20 patients with persistent symptoms of osteoarthritis of the knee were randomly allocated to either a saline washout via a 14-gauge needle or intra-articular saline injection (control group). Both groups had improvement in knee function and pain. The authors concluded that knee washout conferred no more benefit than did intra-articular saline injection.

Chang et al[25] compared the outcomes in patients treated with arthroscopic surgery to outcomes from closed-joint needle lavage (which costs nearly $4,000 less). At 1-year follow-up, 44% of arthroscopically treated patients reported improvement and 58% of the joint lavage group reported improvement. No differences were found in medication costs or use of medical services during the year after the procedures. Despite the success of the closed procedure, some subgroups of patients, particularly those with mechanical symptoms, may benefit more from arthroscopic treatment.[25] However, even patients with severe disease reported benefit from closed-joint needle lavage.

Edelson et al[26] evaluated the short-term effects of washout with 3 liters of lactated Ringer's solution in 29 osteoarthritic knees. At 1-year follow-up, the mean Hospital for Special Surgery score had improved from 72 to 87, the mean Knee Society pain rating from 64 to 89, and the mean Knee Society function rating from 62 to 82. At 1 year, 25 of the 29 subjects (86%) reported good or excellent results, and at 2-year follow-up, 17 of the 21 subjects available (81%) reported good or excellent results. Although this technique does not address the mechanical and functional damage to the articular cartilage of the joint, its temporary success in reducing symptoms of osteoarthritis may offer a less invasive treatment modality. However, a recent study[5] suggested that improvement may be part of a placebo effect.

Meniscectomy

Jackson and Rouse[27] were the first to evaluate partial meniscectomy in an older population (>40 years) with osteoarthritis. They reported 80% excellent or good results at 2.5-year follow-up. Bonamo et al[28] reported that 79% of patients with Outerbridge grades 3 and 4 chondromalacia who underwent partial medial meniscectomy rated their improvement as significant or moderate at 3.3 years. Those with grades 1 and 2 chondromalacia demonstrated better pain relief than did those with grades 3 and 4. McBride et al[29] compared the results of traumatic tears to degenerative tears and noted a 95% satisfaction rate at 3-year follow-up with traumatic tears versus 65% with degenerative tears. In patients with degenerative tears, the presence of advanced osteoarthritis was associated with a less favorable outcome. In their review of 101 cases of isolated meniscectomies, Lotke et al[30] found that patients with normal preoperative radiographs had a greater chance of excellent or good outcomes (90%) than did patients with moderate degenerative changes (21%). Partial meniscectomy in osteoarthritic patients with a documented tear and mechanical symptoms appears to be an effective procedure for the relief of pain at short-term follow-up. However, as the severity of osteoarthritis increases, the results become less favorable.

Treatment Modalities for Articular Cartilage Defects of the Knee

During the past 10 years, several methods have been used to repair or reconstruct both isolateral and diffuse defects in articular cartilage. These techniques include autologous chondrocyte implantation, osteochondral allografts, osteochondral autografts (mosaicplasty), periosteal or perichondral grafting, abrasion arthroplasty, subchondral penetration procedures (ie, drilling and microfracture techniques), laser chondroplasty, and, most recently, thermal chondroplasty using radiofrequency energy. Procedures such as autologous chondrocyte implantation, mosaicplasty, and periosteal/perichondral grafting are not indicated for the knee with global degenerative changes.

Abrasion Arthroplasty and Drilling

Arthroscopic abrasion arthroplasty was pioneered by Johnson,[31] who observed that intracortical defects created in a sclerotic lesion without penetration of the subchondral bone uncovered small blood vessels (Fig. 2). The bleeding that occurred at the abraded cartilage defect resulted in blood clot attachment to the surface, followed by fibrous metaplasia to fibrocartilage; integrity of this reparative tissue can be maintained for up to 6 years postoperatively.[31] A motorized cutting device is currently used to abrade the cartilage defect to a depth of 1 to 2 mm into adjacent cartilage to allow biologic adherence. Weight bearing must be avoided for 8 weeks to allow for fibrocartilage maturation. In his series of 104 patients with degenera-

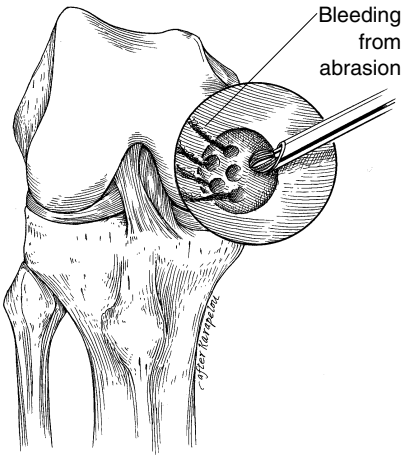

Figure 2 Abrasion arthroplasty involves abrasion of the articular defect with an arthroscopic burr (inset), exposing bleeding bone to allow eventual ingrowth of mesenchymal cells that will lay down fibrocartilage. (Adapted with permission from Miller MD: Atlas of chondral injury treatment. *Op Tech Orthop* 1997;7:289-293.)

tive arthritis, Johnson reported subjective improvement in 78%, no change in 15%, and worsening in 7% at 2-year follow-up.[31]

Subchondral drilling and microfracture of the subchondral bone stimulate the formation of cartilage by disrupting subchondral blood vessels and allowing primitive mesenchymal cells to migrate to the surface and differentiate into chondroblasts and chondrocytes. Theoretically, hyaline-like cartilage would be produced.[32] However, fibrocartilage rather than hyaline cartilage is produced. This is the crux of the strongest criticism of these techniques, that the repair tissue lacks the durability and functional capacity of normal articular cartilage. One study reported repair tissue deterioration within 1 year in a rabbit model.[33]

According to Buckwalter and Mow,[34] tissue formed after the penetration to subchondral bone "lacks the structure, the composition, the mechanical properties and, in most instances the durability of articular cartilage. For these reasons, even though tissue covers the subchondral bone, it may fail to distribute loads across the articular surface in such a way that pain with loading and further degeneration are avoided." Fibrocartilage lacks several key components of hyaline cartilage, such as proteoglycans and other proteins, and is therefore more susceptible to breakdown. Additionally, fibrocartilage has poor wear characteristics compared with normal hyaline cartilage. In one study[35] of abrasion arthroplasty and drilling in medial femoral condyle chondral lesions in rabbits, a substantial decrease in the cartilaginous coverage of the exposed surface and progressive increase in osteoarthritis was observed during the 24-week follow-up. Although penetration of subchondral bone results in the formation of fibrocartilage, no significant correlation has been noted between clinical outcomes and fibrocartilage resurfacing.[36]

Many studies have compared the techniques of débridement with abrasion arthroplasty or drilling procedures.[3,36-38] One study[36] noted a 77% improvement in the débridement group compared with a 39% improvement in the abrasion arthroplasty group for full-thickness defects. In addition, 32% of the abrasion group were worse at 3-year follow-up, with 50% of the abrasion group eventually requiring total knee arthroplasty. The author stated that the results of abrasion arthroplasty were unpredictable.[36] Bert[38] concluded that, although débridement can decrease symptoms in osteoarthritis, subchondral penetration has no benefit and may worsen symptoms. He attributed any symptomatic improvement to irrigation of the joint during the arthroscopy.[3,38] Drilling was abandoned in one controlled trial because many patients suffered severe postoperative pain that hindered their recovery.[17] In a comparison of 59 patients treated by débridement and abrasion with 67 patients treated with débridement alone, successful (good or excellent) outcomes at 5-year follow-up were reported for 51% in the abrasion group and 66% in the débridement group.[37] In addition to less favorable outcomes, the results in the abrasion group deteriorated more rapidly over time.

The investigations of abrasion arthroplasty and drilling techniques indicate that the procedure offers minimal benefit over débridement or lavage alone. Although the value of filling in defects with fibrocartilage appears to be advantageous in theory, clinical follow-up has not demonstrated consistent benefits (Fig. 3). The results of abrasion arthroplasty tend to worsen with time, presumably as a result of deterioration of the load-bearing capability of the reparative fibrocartilage.[3,38]

Microfracture

Steadman's microfracture technique is based on a theory of healing similar to that of abrasion and drilling.[39] The lesion is débrided and subchondral bone exposed. An arthroscopic awl is used to make "microfractures" in the subchondral bone by picking three or four holes per cm^2 to a depth of about 4 mm (Fig. 4). Steadman et al[39] indicated that the benefits of the awl include less thermal necrosis of the subchondral bone compared with drilling or abrasion arthroplasty, maintenance of the integrity of the subchondral bone shape, and a roughened subchondral surface, which allows better adhesion for the clot. They reported a 75% improvement at 3- to 5-year follow-up using the microfracture technique with arthroscopic awls in all patients having the procedure. Continuous passive motion and no weight bearing for 6 to 8 weeks is essential for both the gross healing of the defect and the reduction of pain.[40]

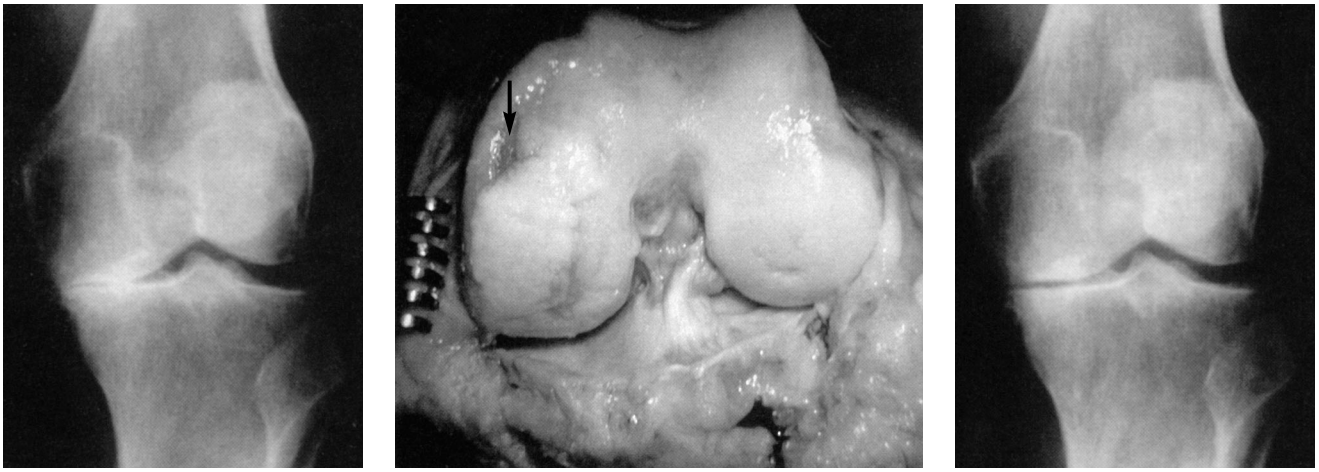

Figure 3 **A,** Weight-bearing anteroposterior radiograph of the left knee in a 58-year-old woman shows advanced medial joint space narrowing. **B,** Intraoperative view at the time of unicompartmental knee replacement shows fibrocartilage formation in the medial femoral condyle after undergoing abrasion arthroplasty (arrow). **C,** Weight-bearing anteroposterior radiograph 2 years after abrasion arthroplasty. A mild increase in the joint space in the medial compartment is evident. The patient's pain worsened despite the increased joint space. (Reproduced with permission from Bert JM: Abrasion arthroplasty. *Op Tech Orthop* 1997;7:294-299.)

Laser and Thermal Chondroplasty

The goal of arthroscopic chondroplasty is to remove diseased articular cartilage using rotary mechanical débriders or hand instruments. Their use can potentially leave behind a roughened surface or result in excessive removal of viable articular cartilage done to ensure adequate débridement.[41,42] Laser chondroplasty initially appeared to overcome these problems, allowing for more precise tissue ablation and improved tissue access. However, high cost and complications such as osteonecrosis secondary to marked subchondral penetration have limited its use.[43,44]

Recently, radiofrequency (RF) energy has been introduced to treat articular cartilage lesions. In principle, RF energy works by smoothing and stabilizing articular cartilage defects. This prevents defect propagation and eventual arthritis and joint dysfunction. RF generators are economic heat sources with a reported high degree of safety.[45,46] They have been used in numerous clinical applications, including tissue ablation and capsular shrinkage. Both bipolar and monopolar probes

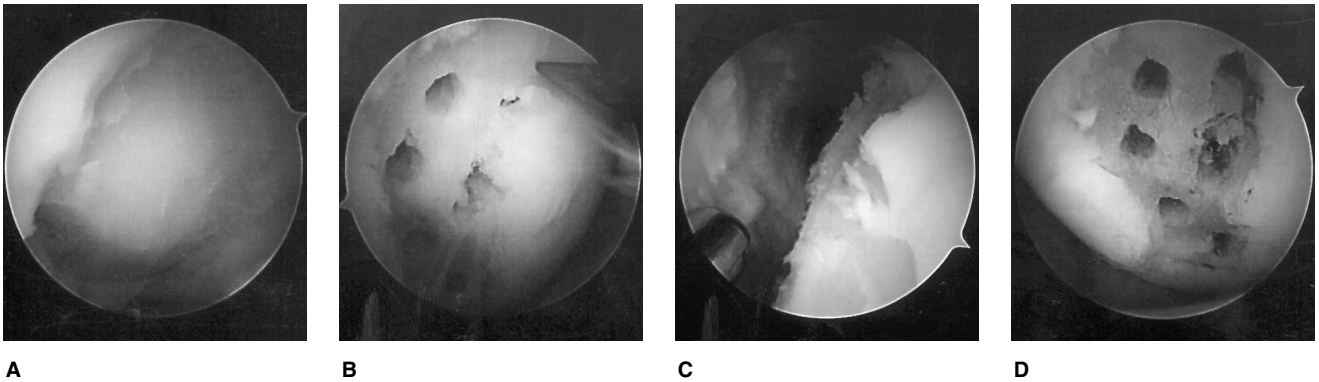

Figure 4 **A,** Arthroscopic view of a medial femoral condyle lesion in the right knee of a 31-year-old woman. **B,** Medial femoral condyle lesion after picking. **C,** Lateral femoral condyle lesion in the same patient. **D,** Lateral lesion after picking. Evidence of blood indicates breakage through the subchondral plate, theoretically allowing mesenchymal cells to proliferate at the site.

are currently available. However, conflicting results have been reported with RF. Kaplan et al[47] demonstrated in vitro smoothing of diseased, fibrillated cartilage with a bipolar probe while viable chondrocytes were left in the treated area, with no collagen alteration. This outcome was supported in vivo in a sheep model by Turner et al,[48] who demonstrated that a smoother surface with greater chondrocyte viability resulted when a bipolar thermal probe was used compared with a traditional mechanical shaver.[48] Others have disputed these findings by demonstrating that RF treatment causes long-term damage to articular cartilage and decreased proteoglycan concentration in a similar sheep model.[46,49] At the present time, therefore, there appears to be no consensus on the use of RF thermal energy on articular cartilage lesions.

Placebo Effect

The fact that some scientific evidence could be found to demonstrate improvement for some patients after these procedures means that further investigation is definitely warranted in the form of double-blind controlled prospective analysis. Such studies can also assess placebo versus direct benefits from débridement and lavage procedures. This would offer the surgeon more concrete facts on which to base treatment. In 1996, Moseley et al[50] conducted the first prospective, randomized, placebo-controlled study. In 10 patients, three alternative treatments were used: lavage, lavage and débridement, and placebo. All patients were brought to the operating room and appropriate anesthesia was administered. The treatment modality was determined in the operating room by opening an envelope that contained instructions specifying one of the three random alternatives. For the placebo group, the regular instruments were called for and the appropriate superficial skin incisions were made; however, no instruments were placed in the joint cavity. Of the 10 patients, 5 had placebo treatment with only the arthroscopic portals created, 3 had lavage alone, and 2 had lavage and débridement. The placebo group reported decreased frequency, intensity, and duration of knee pain. All patients considered the procedure to be worthwhile and would recommend it to family and friends.

This was followed by expanding the study to 180 patients.[5] At 2-year follow-up, the conclusions were still the same: the outcomes of arthroscopic lavage or arthroscopic débridement were no better than those after the placebo procedure. Criticisms of the study include patient selection criteria, particularly lack of a uniform group with osteoarthritis and mechanical symptoms.[51]

Prognostic Factors

Although the overall benefits of these procedures for osteoarthritic patients remain unclear, certain factors have been associated with a better or worse prognosis. Based on the review of the literature, relevant prognostic factors for the success of arthroscopic management of osteoarthritis of the knee can be established (Table 1). Four categories are considered—history and symptoms, physical examination, radiographic findings, and surgical findings.

Sudden onset of symptoms related to trauma or symptoms of mechanical damage are associated with better outcomes.[10,18,30] Physical findings of malalignment and ligament instability are associated with worse outcomes.[14,22,30,52] The extent and severity of disease play an important role in patient outcome. Patients with radiographic findings of loose bodies and normal alignment have better results than do those with evi-

Table 1
Prognostic Factors for Arthroscopic Treatment of Degenerative Arthritis of the Knee

Factor	Good Prognosis	Poor Prognosis
History/symptoms	Increased pain of acute onset, specific twisting mechanism, mechanical symptoms	Pending litigation/work injury, chronic symptoms
Physical examination	Recent effusion	Varus/valgus alignment, ligamentous instability
Radiographic findings	Loose bodies, normal mechanical alignment	Complete loss of joint space, chondrocalcinosis, varus/valgus alignment
Surgical findings	Isolated chondral flap/fracture, isolated unicompartmental disease, meniscal tears	Diffuse disease, degenerative meniscal tears, severe chondromalacia

dence of severe degenerative disease, such as loss of joint space.[10,14,21] Knees with isolated lesions at the time of surgery fare better than do knees with diffuse disease.[10,14,20,21,23,53] One study found a correlation of outcome with the absolute number of pathologic findings and severity of degenerative changes at the time of surgery.[20] In addition, patients who had a higher pretreatment function fared better than did those with more severe dysfunction. Poor clinical results and higher rates of additional surgery also have been observed when severe chondromalacia is present and only eburnated bone remained.[10,14,20,21,23]

Summary

Although arthroscopy is valuable for the treatment of many knee disorders, expectations should be limited when this technology is applied to the arthritic knee. Arthroscopy has the potential to delay definitive reconstructive procedures. Patients with acute onset of pain, mechanical symptoms related to meniscal pathology or to loose bodies or articular cartilage fragments, normal lower extremity alignment, and minimal radiographic evidence of degenerative disease tend to have greater symptomatic relief and more persistent pain relief. Despite this, it is unlikely that the natural history of the disease is altered.

Arthroscopic chondroplasty techniques provide unpredictable results. Primary concerns are durability of the fibrocartilage repair tissue in subchondral penetration procedures and thermal damage to subchondral bone and adjacent normal articular cartilage in laser and RF thermal chondroplasty. Well-designed prospective, randomized, blinded clinical studies with clearly defined entrance criteria and reproducible outcome measures are needed to better define the role of arthroscopy in the management of degenerative arthritis of the knee.

References

1. Burks RT: Arthroscopy and degenerative arthritis of the knee: A review of the literature. *Arthroscopy* 1990;6:43-47.
2. Buckwalter JA, Lohmander S: Operative treatment of osteoarthrosis: Current practice and future development. *J Bone Joint Surg Am* 1994;76:1405-1418.
3. Bert JM: Role of abrasion arthroplasty and debridement in the management of osteoarthritis of the knee. *Rheum Dis Clin North Am* 1993;19:725-739.
4. Jackson RW, Gilbert JE, Sharkey PF: Arthroscopic debridement versus arthroplasty in the osteoarthritic knee. *J Arthroplasty* 1997;12:465-470.
5. Moseley JB, O'Malley K, Petersen NJ, et al: A controlled trial of arthroscopic surgery for osteoarthritis of the knee. *N Engl J Med* 2002;347:81-88.
6. Evans CH, Mazzocchi RA, Nelson DD, Rubash HE: Experimental arthritis induced by intraarticular injection of allogenic cartilaginous particles into rabbit knees. *Arthritis Rheum* 1984;27:200-207.
7. Plank E, Johnson LL: *Diagnostic and Surgical Arthroscopy: The Knee and Other Joints*, ed 2. St. Louis, MO: CV Mosby, 1980.
8. Livesley PJ, Doherty M, Needoff M, Moulton A: Arthroscopic lavage of osteoarthritic knees. *J Bone Joint Surg Br* 1991;73:922-926.
9. Aichroth PM, Patel DV, Moyes ST: A prospective review of arthroscopic debridement for degenerative joint disease of the knee. *Int Orthop* 1991; 15:351-355.
10. Baumgaertner MR, Cannon WD Jr, Vittori JM, Schmidt ES, Maurer RC: Arthroscopic debridement of the arthritic knee. *Clin Orthop* 1990;253: 197-202.
11. Jackson RW, Silver R, Marans H: Abstract: Arthroscopic treatment of degenerative joint disease. *Arthroscopy* 1986;2:114.
12. Jackson RW, Marans HJ, Silver RS: Abstract: The arthroscopic treatment of degenerative arthritis of the knee. *J Bone Joint Surg Br* 1988;70:332.
13. Gibson JN, White MD, Chapman VM, Strachan RK: Arthroscopic lavage and debridement for osteoarthritis of the knee. *J Bone Joint Surg Br* 1992;74: 534-537.
14. Goldman RT, Scuderi GR, Kelly MA: Arthroscopic treatment of the degenerative knee in older athletes. *Clin Sports Med* 1997;16:51-68.
15. Kim HK, Moran ME, Salter RB: The potential for regeneration of articular cartilage in defects created by chondral shaving and subchondral abrasion: An experimental investigation in rabbits. *J Bone Joint Surg Am* 1991;73: 1301-1315.
16. McLaren AC, Blokker CP, Fowler PJ, Roth JN, Rock MG: Arthroscopic debridement of the knee for osteoarthrosis. *Can J Surg* 1991;34:595-598.
17. Insall JN (ed): *Surgery of the Knee*. New York, NY: Churchill Livingstone, 1984.
18. Novak PJ, Bach BR Jr: Selection criteria for knee arthroscopy in the osteoarthritic patient. *Orthop Rev* 1993;22: 798-804.
19. Stuart MJ: Arthroscopic management for degenerative arthritis of the knee. *Instr Course Lect* 1999;48:135-141.
20. Gross DE, Brenner SL, Esformes I, Gross ML: Arthroscopic treatment of degenerative joint disease of the knee. *Orthopedics* 1991;14:1317-1321.
21. Linschoten NJ, Johnson CA: Arthroscopic debridement of knee joint arthritis: Effect of advancing articular degeneration. *J South Orthop Assoc* 1997;6:25-36.
22. Ogilvie-Harris DJ, Fitsialos DP: Arthroscopic management of the degenerative knee. *Arthroscopy* 1991;7:151-157.
23. Friedman MJ, Berasi CC, Fox JM, Del Pizzo W, Snyder SJ, Ferkel RD: Preliminary results with abrasion arthroplasty in the osteoarthritic knee. *Clin Orthop* 1984;182:200-205.
24. Dawes PT, Kirlew C, Haslock I: Saline washout for knee osteoarthritis: Results of a controlled study. *Clin Rheumatol* 1987;6:61-63.
25. Chang RW, Falconer J, Stulberg SD, Arnold WJ, Manheim LM, Dyer AR: A randomized, controlled trial of arthroscopic surgery versus closed-needle joint lavage for patients with osteoarthritis of the knee. *Arthritis Rheum* 1993;36:289-296.
26. Edelson R, Burks RT, Bloebaum RD: Short-term effects of knee washout for osteoarthritis. *Am J Sports Med* 1995; 23:345-349.

27. Jackson RW, Rouse DW: The results of partial arthroscopic meniscectomy in patients over 40 years of age. *J Bone Joint Surg Br* 1982;64:481-485.
28. Bonamo JJ, Kessler KJ, Noah J: Arthroscopic meniscectomy in patients over the age of 40. *Am J Sports Med* 1992;20:422-429.
29. McBride GG, Constine RM, Hofmann AA, Carson RW: Arthroscopic partial medial meniscectomy in the older patient. *J Bone Joint Surg Am* 1984;66:547-551.
30. Lotke PA, Lefkoe RT, Ecker ML: Late results following medial meniscectomy in an older population. *J Bone Joint Surg Am* 1981;63:115-119.
31. Johnson LL: Arthroscopic abrasion arthroplasty: Historical and pathologic perspective: Present status. *Arthroscopy* 1986;2:54-69.
32. Shapiro F, Koide S, Glimcher MJ: Cell origin and differentiation in the repair of full-thickness defects of articular cartilage. *J Bone Joint Surg Am* 1993; 75:532-553.
33. Mitchell N, Shepard N: The resurfacing of adult rabbit articular cartilage by multiple perforations through the subchondral bone. *J Bone Joint Surg Am* 1976;58:230-233.
34. Buckwalter JA, Mow VC: Cartilage repair in osteoarthritis, in Moskowitz RW, Howell DS, Goldberg VM, Mankin HJ (eds): *Osteoarthritis: Diagnosis and Medical/Surgical Management*, ed 2. Philadelphia, PA: WB Saunders, 1992, pp 71-107.
35. Menche DS, Frenkel SR, Blair B, et al: A comparison of abrasion burr arthroplasty and subchondral drilling in the treatment of full-thickness cartilage lesions in the rabbit. *Arthroscopy* 1996; 12:280-286.
36. Rand JA: Role of arthroscopy in osteoarthritis of the knee. *Arthroscopy* 1991; 7:358-363.
37. Bert JM, Maschka K: The arthroscopic treatment of unicompartmental gonarthrosis: A five-year follow-up study of abrasion arthroplasty plus arthroscopic debridement and arthroscopic debridement alone. *Arthroscopy* 1989;5: 25-32.
38. Bert JM: Abrasion arthroplasty. *Op Tech Orthop* 1997;7:294-299.
39. Steadman JR, Rodkey WG, Singleton SB, Briggs KK: Microfracture technique for full-thickness chondral defects: Technique and clinical results. *Op Tech Orthop* 1997;7:300-304.
40. Rodrigo JJ, Steadman JR, Stillman JF, Fulstone HA: Improvement of full-thickness chondral defect healing in the human knee after debridement and microfracture using continuous passive motion. *Am J Knee Surg* 1994; 7:109-116.
41. Jackson RW: Arthroscopic surgery and a new classification system. *Am J Knee Surg* 1998;11:51-54.
42. Gilbert JE: Current treatment options for the restoration of articular cartilage. *Am J Knee Surg* 1998;11:42-46.
43. Grifka J, Boenke S, Schreiner C, Lohnert J: Significance of laser treatment in arthroscopic therapy of degenerative gonarthritis: A prospective, randomised clinical study and experimental research. *Knee Surg Sports Traumatol Arthrosc* 1994;2:88-93.
44. Garino JP, Lotke PA, Sapega AA, Reilly PJ, Esterhai JL Jr: Osteonecrosis of the knee following laser-assisted arthroscopic surgery: A report of six cases. *Arthroscopy* 1995;11:467-474.
45. Hecht P, Hayashi K, Cooley AJ, et al: The thermal effect of monopolar radiofrequency energy on the properties of joint capsule: An in vivo histologic study using a sheep model. *Am J Sports Med* 1998;26:808-814.
46. Lu Y, Hayashi K, Hecht P, et al: The effect of monopolar radiofrequency energy on partial-thickness defects of articular cartilage. *Arthroscopy* 2000; 16:527-536.
47. Kaplan L, Uribe JW, Sasken H, Markarian G: The acute effects of radiofrequency energy in articular cartilage: An in vitro study. *Arthroscopy* 2000; 16:2-5.
48. Turner AS, Tippett JW, Powers BE, Dewell RD, Mallinckrodt CH: Radiofrequency (electrosurgical) ablation of articular cartilage: A study in sheep. *Arthroscopy* 1998;14:585-591.
49. Lu Y, Edwards R III, Hayashi K, et al: The effect of radiofrequency energy on bovine femoral articular cartilage: An *in vitro* comparison of monopolar (Oratec) and bipolar (Mitek) radiofrequency energy. *Trans Orthop Res Soc* 2000;25:903.
50. Moseley JB Jr, Wray NP, Kuykendall D, Willis K, Landon G: Arthroscopic treatment of osteoarthritis of the knee: A prospective, randomized, placebo-controlled trial. Results of a pilot study. *Am J Sports Med* 1996;24:28-34.
51. AAOS responds to NEJM study. *AAOS Bulletin* 2002;50:47,49.
52. Salisbury RB, Nottage WM, Gardner V: The effect of alignment on results in arthroscopic debridement of the degenerative knee. *Clin Orthop* 1985;198: 268-272.
53. Bernstein J: Arthroscopy for osteoarthritis of the knee. *J Musc Med* 1998; 15:43-47.