Treatment of Osteoarthritis of the Knee with Microfracture and Rehabilitation

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ABSTRACT

YEN, Y.-M., B. CASCIO, L. O'BRIEN, S. STALZER, P. J. MILLETT, and J. R. STEADMAN. Treatment of Osteoarthritis of the Knee with Microfracture and Rehabilitation. *Med. Sci. Sports Exerc.*, Vol. 40, No. 2, pp. 200–205, 2008. Microfracture is a single stage arthroscopic procedure that can be used in conjunction with other arthroscopic treatments for the treatment of osteoarthritis of the knee. It has a well-documented and successful track record and when used with the appropriate rehabilitation techniques can be very effective for pain relief and functional improvement. It has proven clinical benefit and is our technique of choice for the initial surgical treatment of osteoarthritis. **Key Words:** ARTICULAR CARTILAGE, SURGICAL TECHNIQUE, PRESERVATION, ARTHROPLASTY ALTERNATIVE

Many patients and providers think of arthroplasty as the only surgical option for the treatment of osteoarthritis of the knee. However, there are several other surgical options for osteoarthritis which can be therapeutic alternatives. Contemporary options include (i) arthroscopic debridement or lavage, (ii) marrow-stimulation techniques, such as microfracture, (iii) periosteal or perichondral grafting, (iv) autologous chondrocyte implantation, (v) osteochondral autograft transplantation, and (vi) osteochondral allograft transplantation.

Each technique offers its own advantages and disadvantages, but there are very few controlled comparative clinical or basic science studies. In the setting of osteoarthritis with full-thickness chondral lesions, there is still debate concerning optimal treatment options.

This review outlines the basic science, approach, and technique of microfracture as well as patient results and rehabilitation protocols in the treatment of osteoarthritis. We prefer this technique to other forms of treatment for several reasons: (i) it is a one-stage procedure that is not as technically demanding as other techniques, (ii) it has a successful, well-documented track record with equal if not better efficacy when compared with other cartilage repair techniques, and (iii) it is inexpensive and can be done as an incidental procedure when articular defects are recognized during other surgeries. Although microfracture does regenerate hyaline-like tissue, the regeneration of true hyaline articular cartilage remains elusive in all surgical techniques that are currently available. We will continue to use microfracture for the treatment of full-thickness articular cartilage defects until a more reliable treatment option is found.

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BASIC SCIENCE

Full-thickness articular cartilage lesions heal unpredictably and usually incompletely. The healing that occurs has been demonstrated to result from recruitment of extrinsic mesenchymal cells from the subchondral bone rather than adjacent chondrocytes. A fibrinous network of clotted blood organizes into a scaffold followed by invasion of capillary vessels from the marrow. Using labeled thymidine in a rabbit model, undifferentiated marrow stem cells migrate into the defect and differentiate into cells resembling chondrocytes (30). The new tissue that is formed is suboptimal with regard to its composition, biochemical and histological properties, and durability (5,30).

Microfracture is a technique in which the subchondral bone is penetrated to stimulate formation of a new articular surface. This began with the idea that augmentation of healing could be enhanced by recruiting marrow elements. Penetration of the subchondral bone disrupts blood vessels and promotes the formation of a fibrin clot. Undifferentiated mesenchymal cells migrate into the clot, proliferate and form a fibrocartilaginous surface. Pridie in the 1950s penetrated the subchondral bone with a drill while Johnson performed superficial abrasion of the chondral surface to promote tissue repair (2,3,6,13,14,16,17,27). The concept of microfracture has been refined and popularized by Steadman and colleagues (4,31,33–35).

Marrow-stimulation techniques produce a fibrocartilaginous surface that has both type I and type II cartilage (8).

Using a horse model, Vachon et al. demonstrated that subchondral drilling improved fibrocartilage formation and volume (38). Mitchell and Shepard showed in a rabbit model that perforations at the articular surface created a hyaline-like tissue (24). Kim et al. showed that subchondral abrasion produced filling of rabbit articular cartilage compared with chondroplasty alone (18). In another well-controlled study, Frisbie et al. demonstrated that microfracture creates type II cartilage within 6 wk in an equine model (8). All these marrow-stimulation techniques have been demonstrated to produce fibrocartilage that can cover cartilage defects with microfracture being the most current, refined technique (23).

SURGICAL TECHNIQUE

Microfracture can be used with full-thickness cartilage defects (Fig. 1). Axial malalignment is considered a relative contraindication for surgery, although microfracture can be done concurrently with a corrective osteotomy as a biological and mechanical treatment (37). Patients who cannot or will not comply with the postoperative regimen should be excluded from microfracture since the postoperative protocol is critical for the success of the procedure. The ideal degenerative arthritis patient has neutral axial alignment; has an isolated, well-contained lesion < 400 mm^2; and is able to comply with the postoperative protocol (23).

Microfracture can be performed at anytime during arthroscopy, but we prefer to perform microfracture after all other necessary arthroscopic procedures so that the marrow elements are not diluted by the arthroscopy fluid. The preparation of the subchondral bone can be done at any time, but the actual perforation into the subchondral bone should be done just before exiting the joint. Microfracture holes should bleed and may exude fat droplets from the marrow which can obscure further arthroscopic visualization. The use of awls with varying angles at the tip allows access to almost any point in the knee, and thus every compartment of the knee is amenable to microfracture (23).

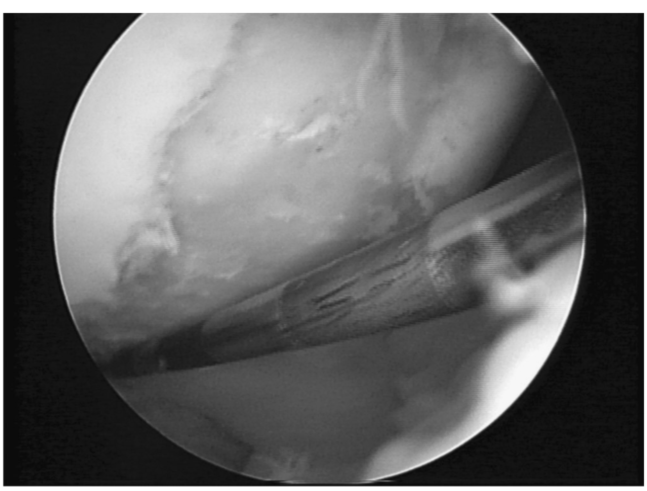

FIGURE 1—Acute full-thickness medial femoral condyle defect. Reprinted with permission from Steadman JR. Microfracture. In: Feagin JA, Steadman JR, editors. *The Crucial Principles in Case of the Knee.* Philadelphia: Lippincott Williams & Wilkins; 2008.p.129–49.

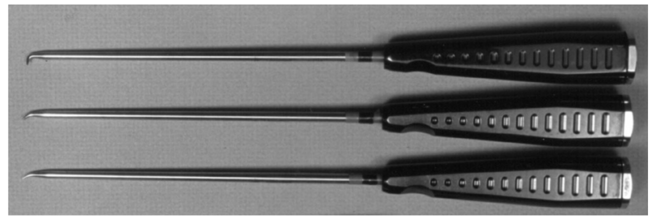

FIGURE 2—Arthroscopic awls used for microfracture.

Preparation of the Defect

To produce a viable route for the marrow elements, the bony bed must be prepared. First, the subchondral bone must be fully exposed and the base of the defect debrided of any soft tissue. The calcified cartilage layer should be removed from the surface of the subchondral bone in order to enhance defect healing (7,9,20). This layer can be removed with a shaver or curette. The subchondral plate should be as completely preserved as possible. Secondly, the boundary of the defect needs to be shouldered by intact articular cartilage. The perimeter of the defect should ideally be perpendicular to the subchondral plate. Unstable delaminated remnants of cartilage should be debrided as they may be a source of persistent pain or propagation of the defect. These can be removed with a shaver initially followed by an angled or ring curette.

Perforation of the Defect

The microfracture of the subchondral plate is then performed with tapered awls and gentle mallet taps. The perforations provide channels for the marrow elements to migrate into the defect. These perforations should be made perpendicular to the subchondral bone and therefore the use of awls rather than drill bits is advised (Fig. 2). Drilling may also cause thermal necrosis of the subchondral bone.

Microfracture is performed first at the periphery of the defect with the holes penetrating approximately 3–4 mm into the subchondral bone. The holes at the periphery may provide optimal anchoring of healing tissue to the transitional zone between the normal articular cartilage. Perforations are then distributed uniformly throughout the defect with 3- to 4-mm bridges of subchondral bone between them (Fig. 3). If the holes are placed too close together, the fractures may coalesce together and propagate at the subchondral bone. The tourniquet (if used) is released and inflow pressure reduced to confirm visualization of blood or fat droplets or both from all the microfracture holes (Fig. 4). If this is not the case, the microfracture can be repeated to ensure marrow extrusion. Additionally, we now perform a thorough inspection of the suprapatellar and infrapatellar pouches, the medial and lateral compartments and address associated pathology such as adhesions and meniscal tears (23).

REHABILITATION

The rehabilitation program after microfracture is critical to ensure a successful outcome for the patient (36). Our protocol is focused on creating an ideal healing environment in which the surgically induced marrow clot is able to mature into durable repair tissue, filling the original defect. The specific rehabilitation program after microfracture surgery varies based on location of the chondral defect. The two protocols that we use after microfracture are presented below. In each, patient compliance is vital to the success of the procedure. These protocols have been specifically designed to work with the microfracture technique and have not been studied in nonmicrofracture patients. We do not believe that patients would benefit from using this rehabilitation protocol if done without microfracture.

Rehabilitation Protocol for Lesions on the Femoral Condyle or Tibial Plateau

Phase I: 0–8 wk. The goals of phase I are to protect the marrow clot, restore full joint range of motion and patellar mobility, restore normal quadriceps function, and decrease joint swelling. After surgery, patients are placed in a continuous passive motion machine (CPM) set at 30–70° and a rate of one cycle per minute. The CPM is used for 6–8 $h \cdot d^{-1}$ for 8 wk. This CPM protocol has demonstrated superior healing when compared to those who did not include CPM in a postoperative regimen (28). Patients who cannot tolerate use of a CPM are instructed to complete 500 flexion–extension passive range of motion exercises three times each day.

To protect the clot created by the microfracture necessitates the patient be touch-down weight bearing for 8 wk postoperatively. No initial postoperative brace is used after a lesion of the femoral condyle or tibial plateau. On resuming full weight-bearing status, a compartmental unloading brace may be considered for patients if biomechanical alignment is considered a contributing cause of the chondral injury.

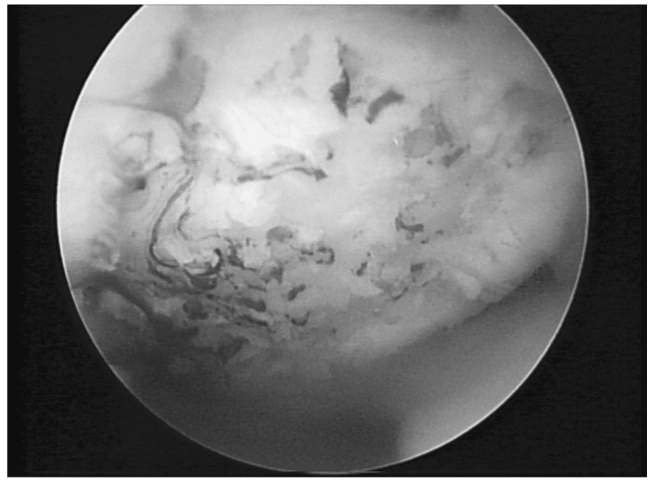

FIGURE 4—Bleeding from perforations confirms appropriate depth of penetration.

Patellar mobilizations are initiated immediately postoperatively and include medial/lateral and superior/inferior movement of the patella, as well as medial/lateral movement of the quadriceps and patellar tendon. This mobilization is considered critical in preventing patellar tendon adhesions, associated increases in patellofemoral and tibiofemoral joint reaction forces (1). Passive flexion/extension exercises are used to restore full knee range of motion. Quadriceps sets and straight leg raises are initiated to restore quadriceps function. Cryotherapy is used for all patients to control and minimize pain and swelling. Ankle pumps are encouraged as a prophylaxis for deep vein thrombosis.

Spinning on a bike with no resistance is initiated at 2 wk postoperatively and progressed as tolerated, with an aim of the patient achieving 45 min of continuous spinning by 8 wk. Deep water running also begins at 2 wk. It is

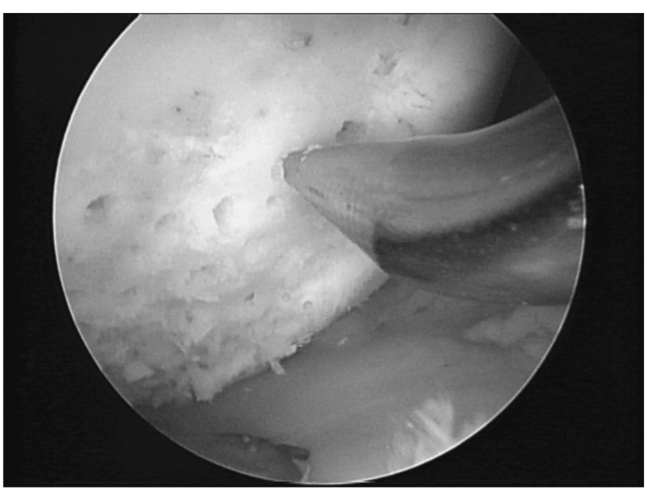

FIGURE 3—Perforations of exposed subchondral bone. Reprinted with permission from Steadman JR. Microfracture. In: Feagin JA, Steadman JR, editors. *The Crucial Principles in Case of the Knee.* Philadelphia: Lippincott Williams & Wilkins; 2008.p.129–49.

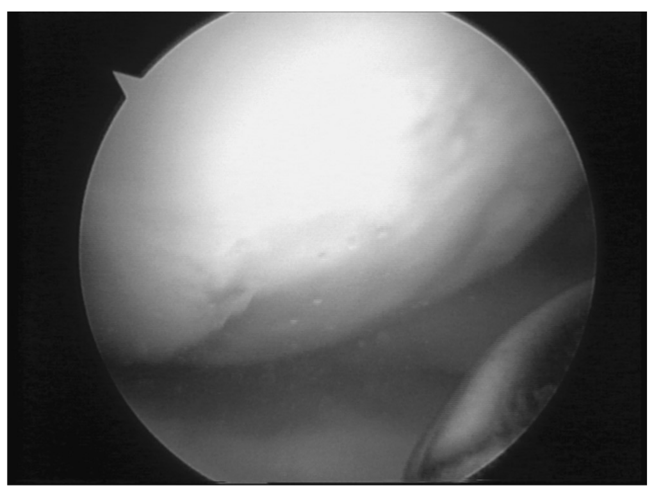

FIGURE 5—Second-look arthroscopy confirming fibrocartilage formation across the defect seen in Figure 1. Reprinted with permission from Steadman JR. Microfracture. In: Feagin JA, Steadman JR, editors. *The Crucial Principles in Case of the Knee.* Philadelphia: Lippincott Williams & Wilkins; 2008.p.129–49.

important that the injured leg remains non–weight bearing during this exercise.

Phase II: 9–16 wk. After completion of the initial 8-wk healing phase, patients are progressed to weight bearing as tolerated, with most patients weaning off crutches over the period of 1 wk. Once full weight bearing and full joint range of motion is achieved, the emphasis of the rehabilitation program shifts from mobility to restoration of normal muscular function and endurance. In this phase of rehabilitation, we use cardiovascular equipment (stationary bike, treadmill, elliptical trainer) in combination with closed-chain, double-leg exercises to achieve rehabilitation goals.

Resistance is gradually added to the bike program, with the goal of achieving 45 min of pain-free cycling. It is necessary to decrease the total time of exercise when first adding resistance, so as not to unnecessarily overload the joint. Treadmill walking on a 7% incline is introduced as well. The impact stress associated with walking dictates that the patient begins with a short duration of 5–10 min, adding 5 $\text{min}\cdot\text{wk}^{-1}$ as tolerated. An elliptical trainer may also be used, and follows the same parameters of treadmill walking.

Closed chain exercises are focused on building an endurance base upon which strength gains can later be made. Initially, one-third double knee bends are used with only body weight for resistance. An elastic resistance cord is added to the regimen around 12 wk. A detailed description of the use of the cord and the exercises has been published previously (12).

Phase III: 17–24 wk. With a muscular endurance base built during phase II, training focuses on regaining strength in the major lower extremity muscle groups. For patients with significant lesions, low impact exercises, such as those outlined in phase II are progressed. For others, sports specific strengthening and lifting techniques are implemented when appropriate. Despite full weight-bearing status, and pain-free performance of loaded activities, caution may still be taken to avoid certain ranges of motion that impact the microfracture site.

A staged running program may begin between 17 and 24 wk, with the determination to start largely dependent on size and severity of the chondral lesion, as well as the patient's sport/recreation. Initial running is completed on a forgiving surface, using 1 min running: 4-min walking intervals. Running time is increased by 1 $\text{min}\cdot\text{wk}^{-1}$ (associated with a 1-min decrease in walking time), so that the patient is able to complete 20 min of continuous running after 5 wk. Initial agility drills are also initiated once the patient is cleared to commence running. Initial agilities are single plane activities completed at 25% of maximum speed, with 25% increases in speed made weekly and progressions to multi plane activities implemented as appropriate.

Phase IV: 25–36 wk. The final phase of the rehabilitation focuses on providing the patient with the performance elements specific to their sport/recreation. Clearance for return to sport is subject to clinical examination. We usually recommend that patients do not return to sports that involve pivoting, cutting and jumping until at least 6–9 months after microfracture.

Rehabilitation Protocol for Patients with Patellofemoral Lesions

All patents are treated with a brace set 0–20° for the first 8 wk postoperatively. This is done to prevent flexion past the point where the median ridge of the patella engages the trochlear groove, thus minimizing the compressive forces on the microfracture site of the trochlear groove, the patella, or both. After 8 wk, the brace is opened gradually before being discontinued.

Patients with patellofemoral lesions are placed in a continuous passive motion machine, set at 0–50°, immediately postoperatively. Apart from the ROM setting, parameters are as for tibiofemoral lesions. While the brace must be worn at all times the patient is not in the CPM, they are allowed to bear partial weight (30% body weight) immediately postoperatively, with a progression to weight bearing as tolerated after 2 wk. Typically, patients are allowed full passive ROM immediately after surgery, however the presence of kissing lesions, multiple defects or defects of significant size may limit ROM parameters. Otherwise, the initial 8-wk rehabilitation process mirrors that for femoral chondyle and tibial plateau lesions.

During completion of the microfracture procedure, particular notice is paid to the femorotibial angle at which the patellofemoral chondral defect is engaged. These angles are avoided during strength training for approximately 4–6 months. Apart from this angle avoidance, the strengthening exercise program is the same as that used for femoral chondyle and tibial chondyle lesions.

RESULTS

There have been numerous clinical studies that support the use of marrow-stimulation techniques (19,20,25,26,28, 31,32,35,36). In 1994, Rodrigo and colleagues reported on "second-look" arthroscopy in 77 patients who had been treated with microfracture (28). The appearance of the defects was graded on a scale of 1 to 5, where 1 is normal and 5 indicates exposed subchondral bone. Among the 46 patients who were able to comply with the postoperative CPM regime, the mean improvement in defect was 2.6, whereas improvement was less dramatic at 1.6 for patients unable to comply with the postoperative therapy (Fig. 5).

In 1997, Steadman et al. reported on the subjective outcomes of microfracture in over 1200 patients from 1985 to 1992 (36). At 3- to 5-yr follow-up, 75% had less pain, 20% had their pain unchanged and 5% were worse. Negative predictors included chronicity of pain, advanced age, and failure to use a CPM. Additionally, Steadman et al. reported on seventy one knees with acute traumatic full-thickness tears of articular cartilage. They excluded patients under 45 and had an average of 11 yr of follow-up. At their latest follow-up, 80% improved, 16% unchanged, and 4% were made worse. They found that age less than 35 was a predictor of better outcome. This is the longest follow-up study with microfracture and demonstrates the effectiveness of this technique (31). Steadman also performed microfracture on 25 National Football League players with full-thickness chondral injuries. The average time of follow-up was 4.5 yr, Lysholm scores increased from 52 to 90 and Tegner scores from 5 to 9. Seventy-six percent returned to play in the NFL and averaged more than 4.6 seasons. Six players retired for various reasons (32).

In 2000, Passler reported on the use of microfracture in 162 patients between 1992 and 1998 (26). At an average of 4.4 yr after surgery, 78% of patients improved, 18% remained unchanged and 4% were worse. This is comparable to the results reported by Steadman et al. (36). Miller et al. reported on patient outcomes after microfracture in 81 patients with degenerative knees (23). Average time of follow-up was 2.6 yr, with Lysholm scores improving from 53.8 to 83.1 and Tegner scores improving from 2.9 to 4.5. There was no association with gender or age, and Lysholm scores improved in all three knee compartments. Bipolar lesions, lesions > 400 mm^2, and patients with absent menisci did not improve as much as smaller focal lesions with retained menisci. Five (5.9%) patients required revision microfracture or conversion to a total knee replacement at an average of 24 months. This group had multiple or bipolar lesions. Thirteen (15.5%) of patients required a repeat arthroscopy for lysis of adhesions within 5 yr (23). We now routinely perform a lysis of adhesions in combination with microfracture in degenerative knees.

Mithoefer et al. recently enrolled 48 symptomatic patients with full-thickness articular cartilage defects of the femur that were treated with microfracture (25). Prospective evaluation of patient outcome was performed with a minimum of 24 months of follow-up. Knee function was good to excellent for 32 patients (67%), fair for 12 patients (25%), and poor for 4 (8%). Activities of daily living scores (ADL), International Knee Documentation Committee scores, and the physical component score of the Short Form-36 (SF-36) all increased after microfracture. The worst results were for a body mass index (BMI) > 30, and a lower BMI correlated with higher scores for ADL and SF-36. Postoperative MRI showed good repair-tissue fill in the defect in 13 patients (54%), moderate fill in 7 (29%), and poor fill in 4 (17%) (25).

Microfracture has been compared with ACI in a prospective randomized trial (19). Eighty patients with a single full-thickness defect on the femoral condyle were treated with either ACI or microfracture. Repeat arthroscopy was conducted at 2 yr for biopsy. At 2 yr, both groups had significant clinical improvement in Tegner and Lysholm scores. The SF-36 physical component score was improved for microfracture. Histologically, the results were comparable in regenerated tissue. These results suggest that microfracture and ACI are comparable techniques; however, given the cost, technical difficulty, and extra surgery, we prefer microfracture to ACI.

There have been two studies comparing microfracture with arthroscopic osteochondral autograft transplantation (OATS) from the same group (10,11). Fifty-seven young competitive athletes (mean age 24.3) were randomized to either microfracture or OATS. All patients were evaluated clinically and 58% of patients underwent repeat arthroscopy for biopsy at 12 months. After 37 months, both groups had significant clinical improvement, however, the modified Hospital for Special Surgery and International Cartilage Repair Society score were rated as excellent or good in 96% of the OATS group compared to 52% of the microfracture group. The histological and MRI examination postoperatively showed an improved score for OATS compared with microfracture. There was one failure in the OATS group and 9 in the microfracture group who then underwent the OATS procedure. Twenty-six (93%) OATS patients and 15 (52%) microfracture patients returned to sports activities at the preinjury level at an average of 6.5 months. However, the rehabilitation protocol differed significantly from what we recommend. There was no use of a CPM, and weight bearing was allowed at 4 wk. It is our opinion that both these factors could adversely affect the quality of the microfracture and compromise the results of these studies.

We believe that the use of this specific rehabilitation protocol is vital to the success of the microfracture technique in osteoarthritis. However, there have been no randomized studies comparing different rehabilitation protocols with respect to microfracture in osteoarthritis. Marder et al. preformed a case control study that showed no difference in the use of a CPM and non–weight bearing compared with full weight bearing and no CPM use in patients with small chondral defects (22). However, these chondral lesions were well shouldered and small, and they are not representative of the lesions seen in osteoarthritis. Additionally, Salter et al. and Rodrigo et al. have shown that use of a CPM results in a more hyaline-like cartilage repair tissue (28,29). There is also evidence that joint loading in a lesion that is not well shouldered leads to disruption of the repair tissue (15,21).

SUMMARY

Microfracture is a technique of cartilage restoration that has been proven to provide clinical benefit in the osteoarthritic knee. It is a relatively simple procedure that can be done concurrently with other arthroscopic procedures and requires minimal equipment. Appropriate patient selection, those with minimal malalignment and ability to adhere to the postoperative regimen is vital. Patients with multiple or bipolar lesions and those with large nonfocal chondral lesions are less likely to achieve long-term benefit. The success of microfracture depends upon surgical technique and the rehabilitation after surgery. Additionally, we now routinely incorporate an extensive surgical lysis of adhesions and rehabilitation to prevent adhesions as part of our protocol. No studies have been conducted that compares rehabilitation alone with microfracture. Although rehabilitation is used commonly in nonoperative treatment protocols for osteoarthritis, it does not directly address the underlying chondral defect that microfracture does. We will continue to perform microfracture for full-thickness cartilage defects until a clearly proven superior technique emerges. In our opinion, such data do not exist, and other techniques are more technically demanding, expensive, and have a higher risk of patient morbidity (23,31,33,36).

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