Chondral Resurfacing of Articular Cartilage Defects in the Knee with the Microfracture Technique

Surgical Technique

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ABSTRACT

BACKGROUND:
Microfracture is a frequently used technique for the repair of articular cartilage lesions of the knee. Despite the popularity of the technique, prospective information about the clinical results after microfracture is still limited. The purpose of our study was to identify the factors that affect the clinical outcome from this cartilage repair technique.

METHODS:
Forty-eight symptomatic patients with isolated full-thickness articular cartilage defects of the femur in a stable knee were treated with the microfracture technique. Prospective evaluation of patient outcome was performed for a minimum follow-up of twenty-four months with a combination of validated outcome scores, subjective clinical rating, and cartilage-sensitive magnetic resonance imaging.

INTRODUCTION

Articular cartilage lesions are diagnosed with increasing frequency and are often associated with substantial morbidity and functional limitation[1,2]. Because of its minimal invasiveness, technical ease, limited surgical morbidity, and high cost-effectiveness, microfracture repair is a frequently used first-line treatment option for full-thickness articular cartilage defects in the knee and is increasingly applied to other joints[3]. Clinical data have indicated that the clinical outcome after microfracture is associated with better repair cartilage filling and that patients with poor-quality filling have limited functional improvement[4]. The use of a systematic surgical approach with attention to subtle technical details can help to optimize cartilage repair after microfracture, thereby optimizing clinical outcome.

SURGICAL TECHNIQUE

Symptomatic articular cartilage defects are typically discovered with use of cartilage-sensitive magnetic resonance imaging; clinical correlation is recommended. Once the decision has been made to proceed with a cartilage restorative procedure, microfracture should be considered as a first-line treatment. The ideal knee lesion should be isolated, well contained, and not exceed an area of 4 cm^2 (2 × 2 cm).

The patient is placed in a supine position, and a general or regional anesthetic is administered. Positioning of the extremity must allow knee motion without limitation. A tourniquet is placed on the proximal aspect of the thigh but is not routinely inflated. The leg is covered with an impermeable stockinette and is wrapped with an ad-

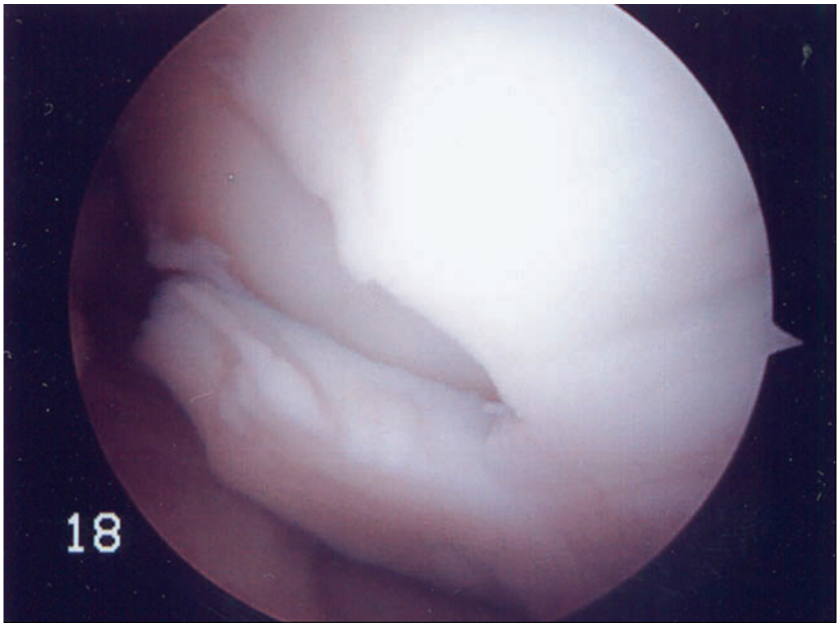


FIG. 1-A

Arthroscopic image demonstrating the primary presentation of a femoral cartilage lesion with a large marginal cartilage flap on probing.

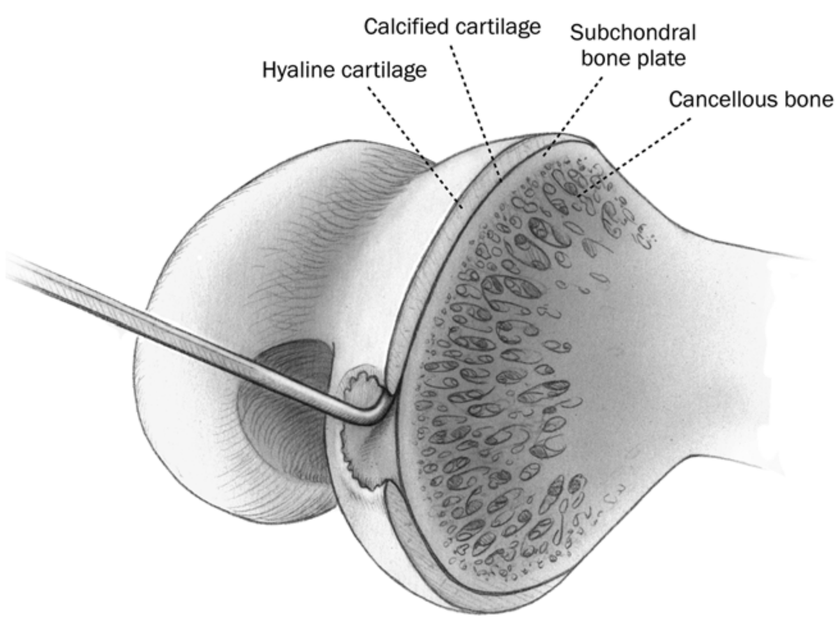


FIG. 1-B

Schematic drawing demonstrating the typical presentation of an articular cartilage lesion upon primary arthroscopic inspection.

ABSTRACT | continued

RESULTS:
At the time of the latest follow-up, knee function was rated good to excellent for thirty-two patients (67%), fair for twelve patients (25%), and poor for four (8%). Significant increases in the activities of daily living scores, International Knee Documentation Committee scores, and the physical component score of the Short Form-36 were demonstrated after microfracture ($p < 0.05$). A lower body-mass index correlated with higher scores for the activities of daily living and SF-36 physical component, with the worst results for patients with a body-mass index of >30 kg/m^2. Significant improvement in the activities of daily living score was more frequent with a preoperative duration of symptoms of less than twelve months ($p < 0.05$). Magnetic resonance imaging in twenty-four knees demonstrated good repair-tissue fill in the defect in thirteen patients (54%), moderate fill in seven (29%), and poor fill in four patients (17%). The fill grade correlated with the knee function scores. All knees with good fill demonstrated improved knee function, whereas poor fill grade was associated with limited improvement and decreasing functional scores after twenty-four months.

CONCLUSIONS:
Microfracture repair of articular cartilage lesions in the knee results in significant functional improvement at a minimum follow-up of two years. The best short-term results are observed with good fill grade, low body-mass index, and a short duration of preoperative symptoms. A high body-mass index adversely affects short-term outcome, and a poor fill grade is associated with limited short-term durability.

hesive bandage. Arthroscopy portals are positioned according to the location of the cartilage lesion to provide optimal access to the articular cartilage defect. Standard anterolateral and anteromedial portals can be used for lesions of the central femoral condyles. For defects of the posterior condyles, portals should be placed lower to facilitate access and visualization of the defects. Farther medial or lateral portals can be added if necessary. Superolateral portals can be helpful for patellar and trochlear lesions. A thorough examination with diagnostic arthroscopy is performed to identify any additional intra-articular abnormalities, such as meniscal tears, ligament disruption, patellar maltracking, or multiple cartilage defects. A meniscal abnormality is treated before microfracture, while ligament reconstruction is performed after microfracture to allow for better visualization of the cartilage lesion. This single-stage approach avoids the repetitive operative morbidity and associated prolonged rehabilitation[5].

The cartilage defect is identified (Figs. 1-A and 1-B), and existing cartilage flaps are débrided back to a stable and healthy peripheral margin with use of an arthroscopic shaver or ring curet (Figs. 2-A and 2-B). The size of the articular lesion is measured with a calibrated probe and recorded. If débridement reveals that the lesion is not contained by an intact cartilage margin, microfracture cannot be

FIG. 2-A

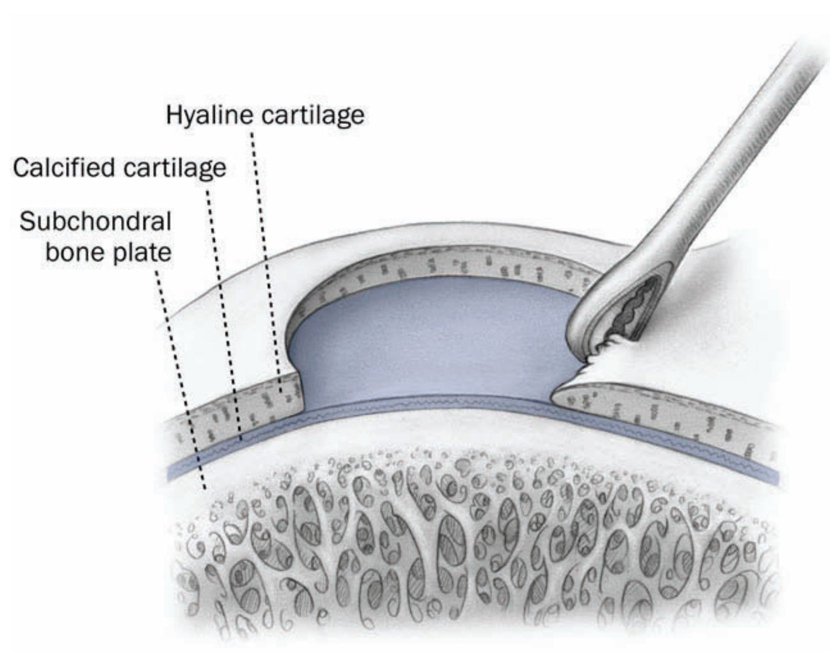


FIG. 2-B

Arthroscopic image (Fig. 2-A) and schematic drawing (Fig. 2-B) demonstrating débridement, with use of an arthroscopic shaver, of any loose cartilage flaps to create a stable peripheral cartilage margin.

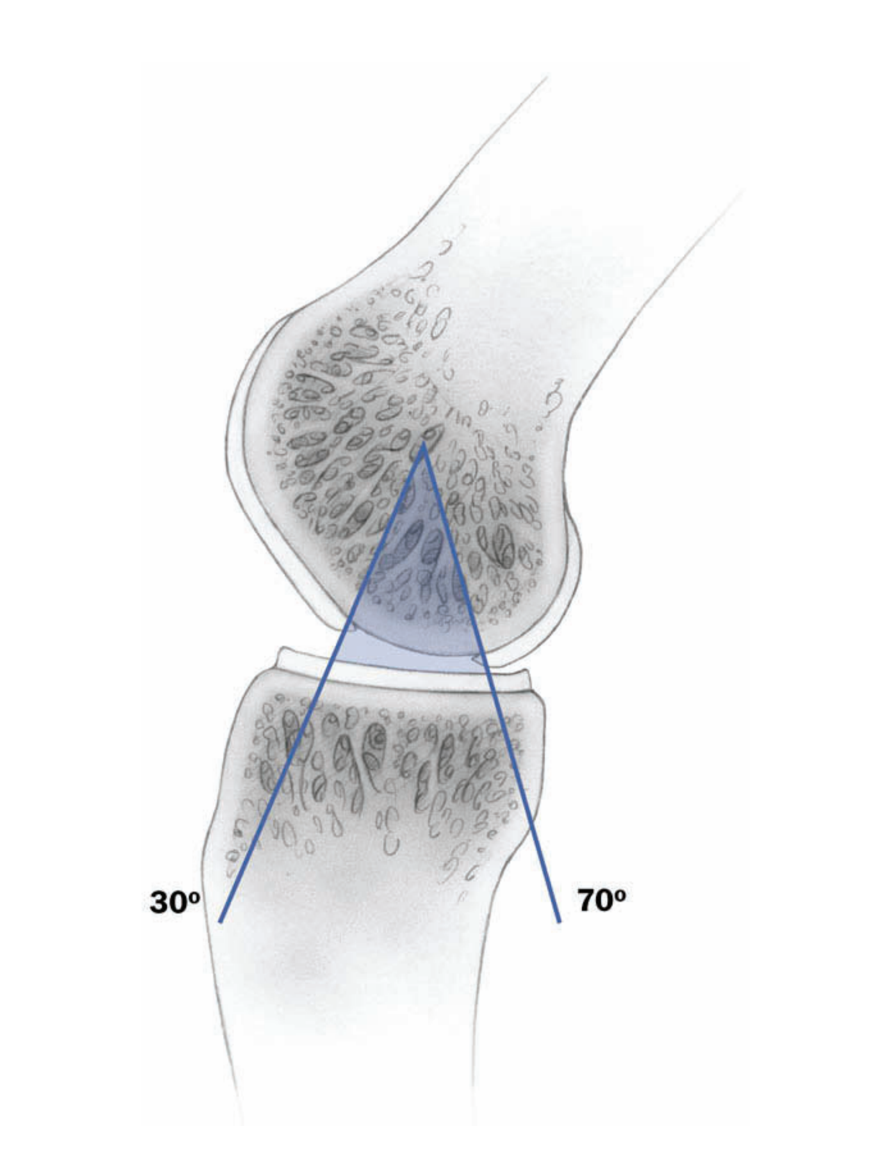


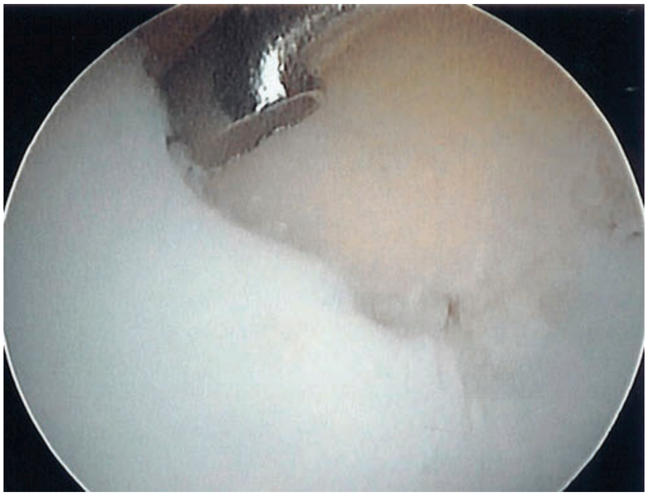
FIG. 3

Schematic drawing illustrating the range of motion during which the cartilage defect articulates with the opposing joint surface.

used since sufficient pooling of the marrow clot in the bed of the lesion cannot be achieved. The arc of motion during which the lesion articulates with the opposing joint surface should be carefully recorded (Fig. 3), as knowledge of this range of contact has important implications for postoperative rehabilitation.

A curet is then used to carefully remove the calcified cartilage layer from the base of the lesion (Figs. 4-A and 4-B). The calcified cartilage comprises a thin layer between the deep zone of the cartilage and the subchondral bone and can increase in thickness with age. Removal of the calcified cartilage has been shown to improve the bonding of the repair tissue to the subchondral bone after microfracture[6]. The calcified cartilage can be difficult to differentiate visually but can be distinguished more easily from the hard underlying subchondral bone plate by tactile feedback. The use of a curet provides better manual feedback than the use of an arthroscopic shaver and reduces the risk of excessive débridement with thinning of the subchondral bone. Excessive removal of the subchondral bone may stimulate subchondral bone overgrowth. This phenomenon has been observed in 25% to 49% of patients after microfracture of the knee and leads to relative thinning of the overlying repair cartilage layer with resultant adverse biologic and biomechanical implications for the repair tissue quality[4,7] (Fig. 5).

Following appropriate removal of the calcified cartilage layer, microfracture holes are created with use of commercially available awls (Linvatec, Largo, Florida) (Fig. 6). The use of these awls avoids the heat necrosis that has been described after marrow stimulation with use of the Pridie drilling technique. The conical shape of the instruments is designed for controlled depth penetration and easy removal of the impacted instrument tip. Penetration of the subchondral bone is performed with the instrument tip placed perpendicular to the subchondral bone plate. Per-



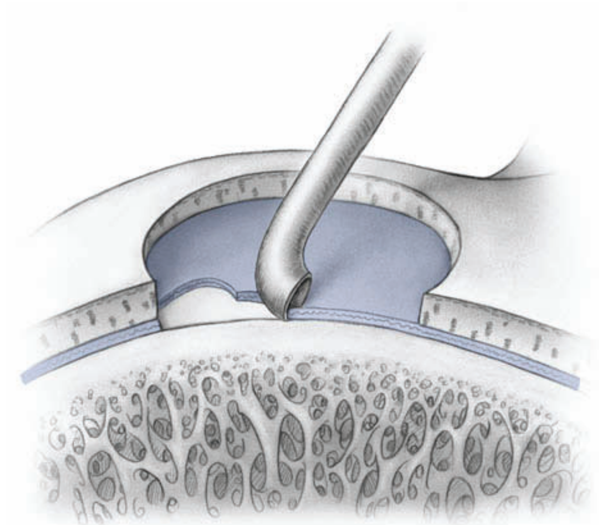


FIG. 4-A

FIG. 4-B

Arthroscopic image (Fig. 4-A) and drawing (Fig. 4-B) showing the intraoperative débridement of the calcified cartilage layer with use of a curet to provide manual feedback control.

CRITICAL CONCEPTS

INDICATIONS:

- Symptomatic, focal high-grade chondral lesions of the weight-bearing femoral condyles, trochlea, and patella in active patients. (The clinical symptoms of articular cartilage lesions are nonspecific, but patients often complain about activity-related pain, swelling, locking, and, in particular, catching. Symptoms can be subtle and difficult to distinguish from the clinical signs of a meniscal abnormality.)
- Incidental cartilage lesions.
- A defect size of <4 cm^2.
- A short preoperative duration of symptoms (optimally, less than twelve months).
- Optimal patient age should be less than forty-five years.

FIG. 5

Sagittal fast-spin-echo magnetic resonance image demonstrating marked subchondral overgrowth (arrow) with resultant thinning of the overlying repair cartilage.

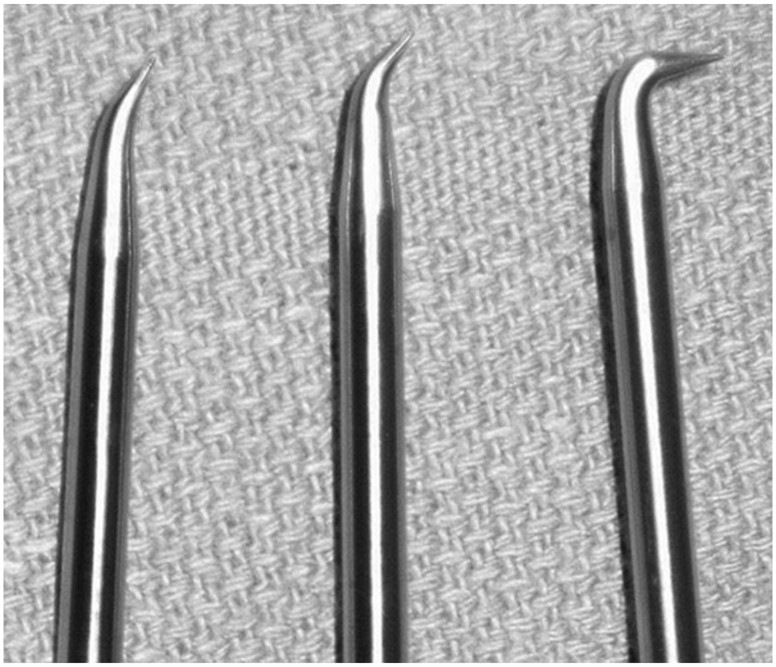


FIG. 6

Photograph showing arthroscopic awl tips with conical shape angulations of 30°, 45°, and 90°.

CRITICAL CONCEPTS | continued

CONTRAINDICATIONS:

Absolute Contraindications:

- Generalized degenerative joint changes
- Limited patient compliance
- Uncontained chondral lesions
- Severe axial malalignment of >5° for lesions of the femoral condyle (surgical realignment required)
- Patellar maltracking or instability for patellofemoral lesions
- High-grade ligament instability (surgical stabilization required for translation of >10 mm to limit postoperative shear forces on the repair cartilage tissue)
- Tumor
- Infection
- Inflammatory arthropathy
- Systemic cartilage disorders

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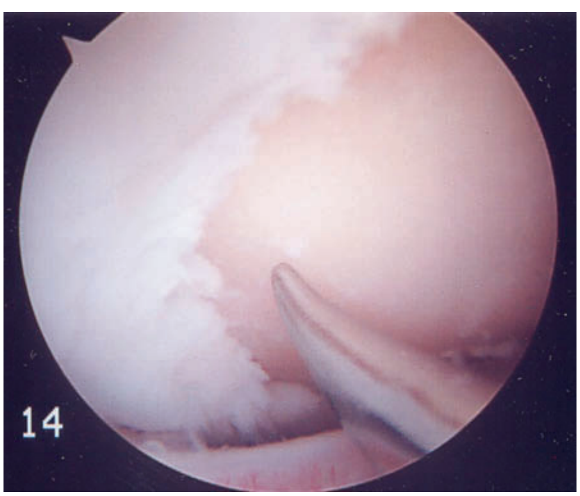

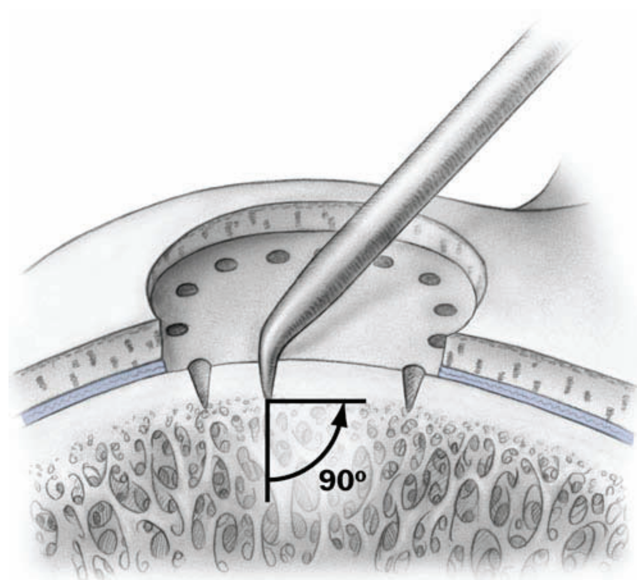

FIG. 7-A FIG. 7-B

Arthroscopic image (Fig. 7-A) and drawing (Fig. 7-B) illustrating the initiation of the microfracture penetrations at the periphery of the lesion with perpendicular alignment of the awl for optimal penetration of the subchondral bone plate.

CRITICAL CONCEPTS | continued

Relative Contraindications:
- Symptoms for more than twelve months
- Body-mass index of >30
- Meniscal deficiency
- Moderate joint degeneration
- A defect size of >4 cm^2
- Patient age of more than sixty years

PITFALLS:
- Insufficient débridement to a stable peripheral cartilage margin and failure to remove the calcified cartilage layer can limit attachment of the repair tissue to the subchondral bone and surrounding intact cartilage.
- Subchondral bone-plate integrity and function may become compromised as a result of subchondral bone-plate collapse resulting from limited distances left between individual microfracture holes, large defects created by skiving instruments, or thinning of the subchondral bone plate from excessive calcified cartilage débridement.
- Arthroscopic microfracture of patellar lesions can be technically challenging. Use of a miniarthrotomy may be beneficial for the inexperienced surgeon.
- Insufficient penetration of subchondral bone and a low density of microfracture penetrations may reduce the quality and quantity of the repair cartilage tissue.
- Poor cartilage filling volume limits the durability of functional improvement after microfracture.
- Premature weight-bearing can lead to displacement of the clot or can limit its attachment to the

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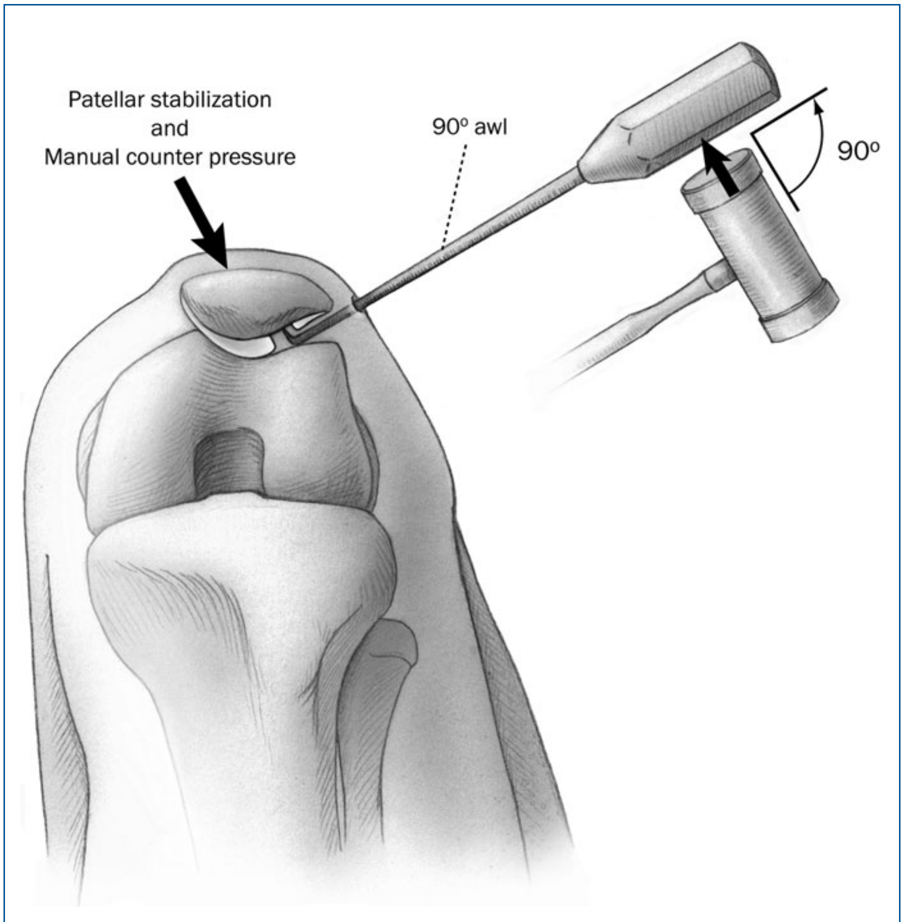


FIG. 8

Drawing illustrating the technique for microfracture of patellar lesions.

pendicular alignment ensures appropriate depth of penetration into the subchondral bone marrow and avoids skiving of the tip during impact with the mallet. Skiving of the instrument can create large longitudinal disruptions of the subchondral bone plate, which may affect its biomechanical integrity. Skiving can also be avoided by gently toeing in the tip of the instrument. Microfracture awls are available with a tip angulation of 30°, 45°, and 90°. The different angles of the arthroscopic awls allow for ready access to cartilage lesions in all areas of the knee joint. For femoral condylar or trochlear lesions, the 30° or 45° awls readily allow this perpendicular alignment (Figs. 7-A and 7-B). Intraoperative knee motion can also help to optimize instrument positioning. The 90° awl is frequently used for patellar defects. Perpendicular penetration of the 90° awl through the patellar subchondral bone plate is facilitated by impacting the side of the handle of the instrument rather than its end. This technique in combination with manual stabilization and counterpressure on the pa-

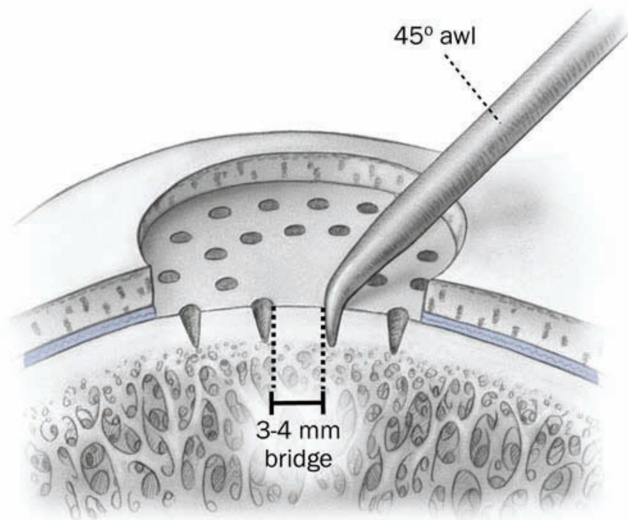


FIG. 9-A

FIG. 9-B

Arthroscopic image (Fig. 9-A) and drawing (Fig. 9-B) demonstrating the adequate depth of subchondral bone penetration and width of osseous bridges between the individual microfracture holes.

tella helps to prevent skiving of the instrument (Fig. 8).

The microfracture holes are created on the periphery of the defect first and then are continued toward the center of the lesion with use of a systematic spiral pattern (Figs. 9-A through 10-B). This systematic approach provides homogeneous distribution of the microfracture holes throughout the entire cartilage defect and maximizes adherence of the mesenchymal clot at the base. Three to four-millimeter-wide bone bridges are carefully maintained between the individual holes to preserve the integrity and function of the subchondral bone plate. The release of fatty droplets from the microfracture holes indicates that adequate depth of the microfracture has been achieved. Once the entire defect has been treated, the osseous debris on the rim of the microfracture holes is removed by curettage or with an arthroscopic shaver. Adequate release of blood and marrow fat droplets from the microfracture holes can be confirmed by eliminating the arthroscopic pump pressure (Figs. 11-A and 11-B). Once adequate access to the subchondral bone marrow has been ensured, the arthroscope is removed from the joint. No drains are used so as to avoid the removal of the pluripotent mesenchymal clot from the cartilage defect by suction or direct abrasion by the drain during postoperative joint mobilization. A compression dressing is placed, and cryotherapy is used routinely for the control of postoperative swelling.

In patients with a lesion of the femoral condyle, continuous passive motion is started in the

CRITICAL CONCEPTS | continued

surrounding cartilage or base. Careful patient selection and close cooperation with well-trained physical therapists will improve compliance with the postoperative rehabilitation protocol.

- Transient postoperative swelling and pain may be observed after microfracture of patellofemoral defects. A clicking sensation may occur during continuous passive motion with larger trochlear lesions as a result of engagement of the patellar tip and the edge of the defect. Most patients improve spontaneously with increasing volume and stiffness of the repair tissue. Patients with associated pain predictably improve with aggressive cryotherapy and limited-arc range of motion that avoids the painful area of motion.

CRITICAL CONCEPTS | continued

AUTHOR UPDATE:
There have been no changes in the surgical techniques since publication of the original article.

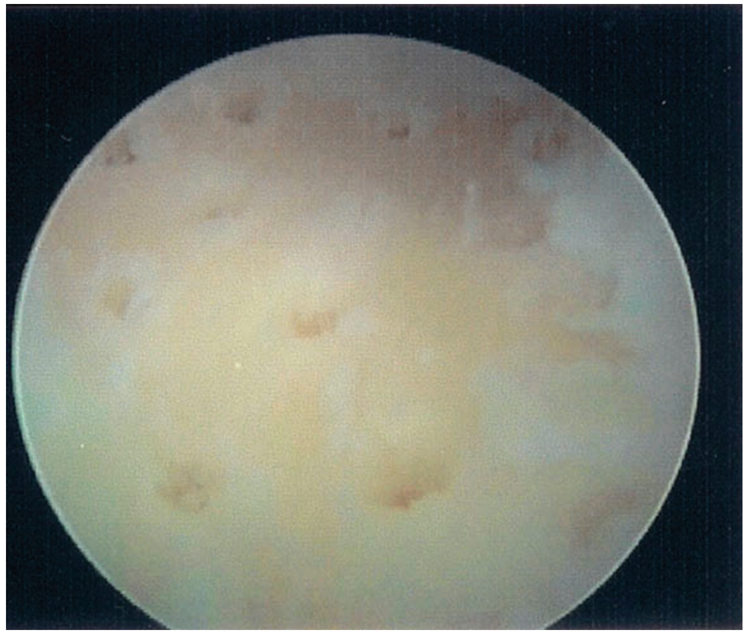


FIG. 10-A

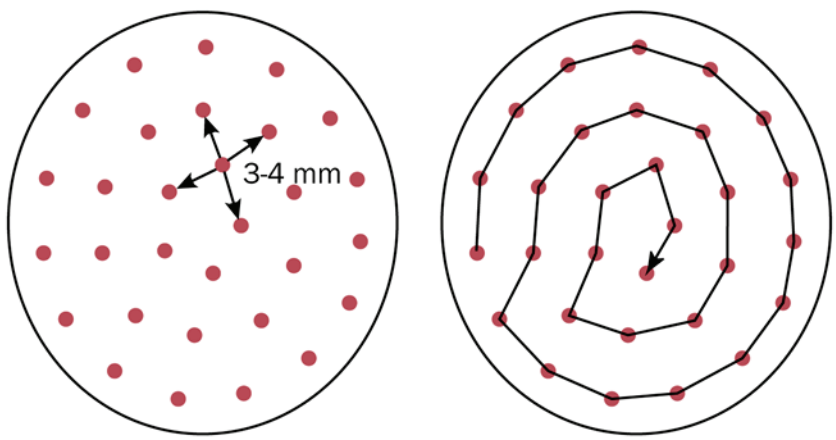
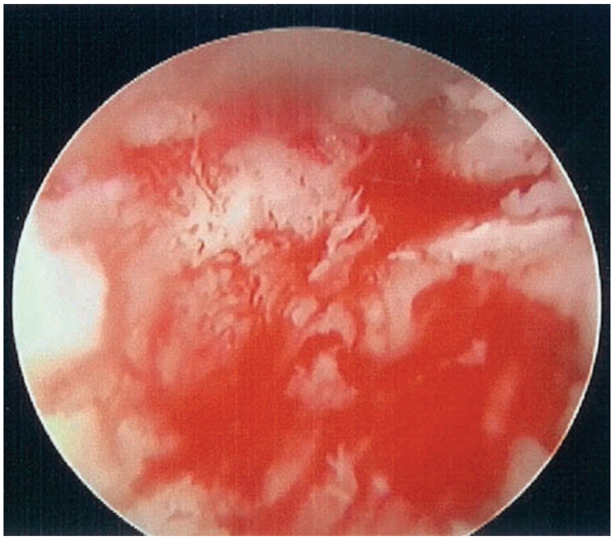


FIG. 10-B

Intraoperative image (Fig. 10-A) and drawing (Fig. 10-B) illustrating the systematic spiral pattern of microfracture penetrations of the subchondral bone plate throughout the cartilage lesion, allowing for a homogeneous distribution of the microfractures while maintaining sufficient subchondral bone bridges between individual penetrations.

recovery room from 0° to 60° and then is gradually increased until full passive motion is achieved. Continuous passive motion provides cartilage nutrition and stimulates mesenchymal stem-cell differentiation in the clot while avoiding the creation of detrimental compression and shear forces on the fragile initial clot. Continuous passive motion is used for a minimum of six hours per day for six weeks. Weight-bearing is avoided for at least six weeks, and then the patient is gradually advanced to full weight-bearing, depending on the size and location of the lesion and the symptoms. Closed-kinetic-chain exercises, such as stationary bicycling, are allowed at two weeks. Limited-arc strengthening exercises are initiated in the range of motion that avoids contact with the repaired lesion (as was determined intraoperatively; see Figure 3). Low-impact activities are advanced on the basis of the symptoms and the magnetic resonance imaging evaluation of the repair tissue. Running is usually allowed at four months after surgery. Cutting and pivoting exercises are allowed at five to six months, and a return to high-impact athletic or professional activities can usually be achieved by six to eight months. Concomitant ligament reconstruction, meniscal surgery, or high tibial osteotomy do not alter the postoperative rehabilitation protocol for condylar lesions treated with microfracture.

Patients with patellofemoral lesions (patella and trochlea) are kept non-weight-bearing with the use of continuous passive motion from 0° to 30° for



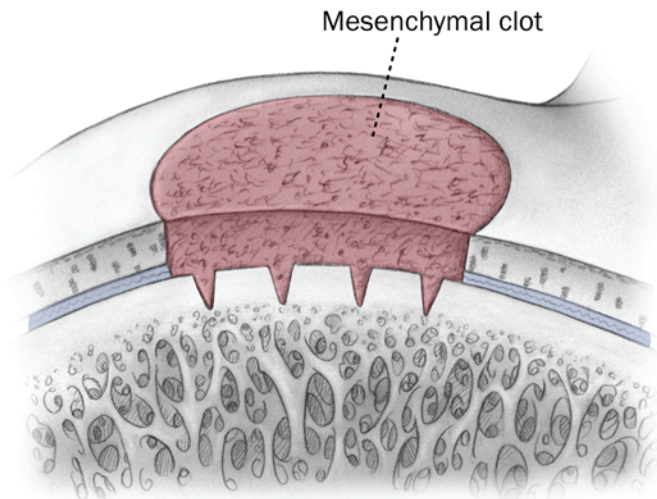


FIG. 11-A FIG. 11-B

Fig. 11-A Arthroscopic image of the treated defect after release of pump pressure, confirming the adequacy of the microfractures by noting the release of fat droplets and blood from the individual holes. **Fig. 11-B** Schematic drawing showing the pooling of the mesenchymal clot in the treated cartilage defect and the anchoring effect of the microfracture penetrations.

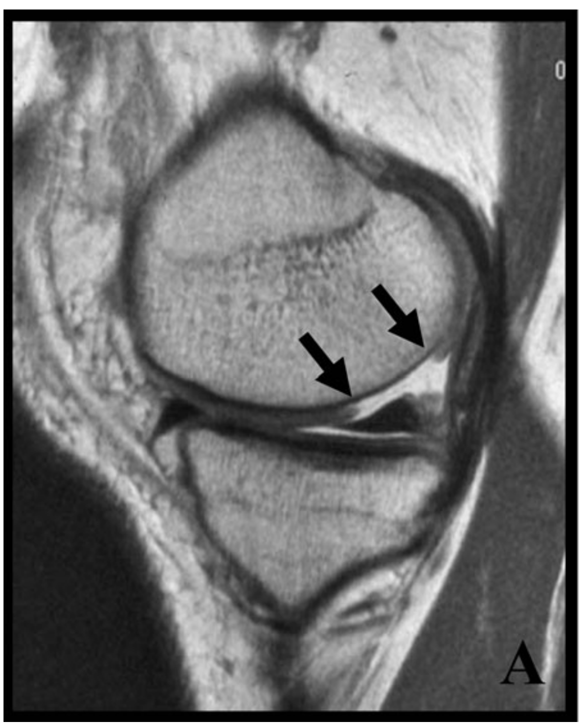


FIG. 12-A FIG. 12-B

Sagittal fast-spin-echo magnetic resonance image of the knee showing a high-grade lesion (arrows) of the medial femoral condyle before (Fig. 12-A) and after cartilage repair with microfracture chondroplasty (Fig. 12-B).

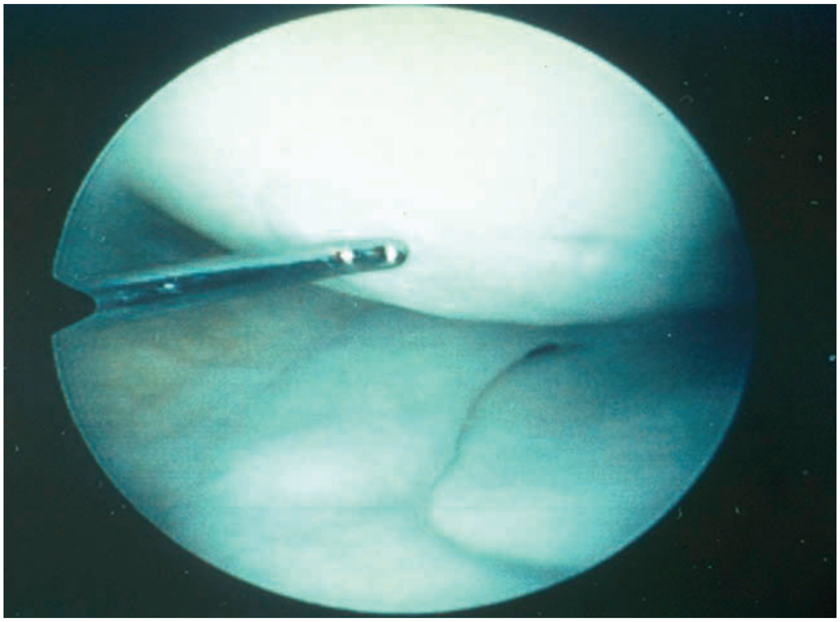


FIG. 13

Arthroscopic appearance of the repaired cartilage defect sixteen months after microfracture.

forty-eight hours. Full weight-bearing is then allowed but with the patient wearing a hinged knee brace that is locked in full extension to avoid the contact and shear forces generated by knee flexion. Continuous passive motion is advanced as tolerated and is used at least six hours a day for six weeks. The range of motion is individually modified on the basis of the location of the lesion and patellar contact pattern observed at the time of surgery. After four weeks, closed-kinetic-chain exercises, such as stationary bicycling, are allowed with the seat elevated. Open-kinetic-chain exercises are avoided until three to four months after microfracture. Rehabilitation may be modified to accommodate simultaneous adjuvant procedures for patellar realignment.

Second-look arthroscopy is not routinely performed. Postoperative cartilage-sensitive magnetic resonance imaging provides reliable information about repair cartilage filling and integration with additional evaluation of the underlying subchondral bone plate with respect to integrity and overgrowth (Figs. 12-A, 12-B, and 13).

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