Arthroscopic Knee Cartilage Repair With Covered Microfracture and Bone Marrow Concentrate

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Abstract: In recent years several single-stage cartilage repair approaches have been devised to treat focal cartilage lesions. These usually associate microfracture (MFX) and a coverage scaffold. We describe a novel arthroscopic technique that combines MFX, autologous bone marrow concentrate (BMC), and a protective scaffold. Bone marrow aspirate from the iliac crest is centrifuged to obtain BMC. The cartilage defect is debrided, MFX holes are created, and the final defect is measured by use of a bent K-wire. The scaffold is then shaped to match the defect, immersed in BMC, introduced into the joint with a grasper, and fixed in place with a mixture of fibrin glue and BMC. This technique aims to augment the original single-stage procedure with a number of mesenchymal stem cells and growth factors contained in the BMC, to increase the defect filling and the rate of hyaline-like cartilage regeneration. The procedure combining MFX, BMC, and a protective scaffold is inexpensive and reproducible and has already shown the ability to regenerate hyaline-like cartilage. Its use as an alternative to autologous chondrocyte implantation requires further investigation.

In recent years, to reduce the cost and the morbidity of autologous chondrocyte implantation and autologous chondrocyte implantation–related cartilage repair procedures, the so-called single stage techniques have been devised. They combine microfracture (MFX), to promote migration of mesenchymal stem cells (MSCs) from subchondral bone, and a protective scaffold to hold them in situ and serve as a support for tissue differentiation.[1,2] The procedures in use mainly differ with regard to the type of scaffold adopted (collagenic[1,3-5] or polyglycolic acid–hyaluronan based[2,6,7]) and the surgical approach (arthroscopic[2,7] or mini-open[1,3-6]). These techniques have led to good clinical and functional results; however, the capability to obtain complete filling of the cartilage defect was shown to be limited.[1,5,6]

Intra-articular delivery of bone marrow concentrate (BMC) has been documented to improve MFX outcome in full-thickness cartilage defects in a horse model.[8] Moreover, compared with tibial or femoral bone marrow blood, BMC from the iliac crest contains greater MSC concentrations with greater doubling potential.[9] This had led to combining MFX, BMC, and a protective scaffold to treat talar chondral lesions, resulting in complete filling of the cartilage defect and a hyaline-like quality of the repair tissue.[10] The purpose of augmenting a single stage procedure with BMC is therefore to deliver to the defect site a larger number of multipotent cells able to differentiate toward the chondral lineage and, ultimately, to improve the defect filling and the rate of hyaline-like repair.[8]

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The authors report that they have no conflicts of interest in the authorship and publication of this article.

Received June 8, 2012; accepted July 2, 2012.

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2212-6287/12383/$36.00

http://dx.doi.org/10.1016/j.eats.2012.07.001

The aim of this technical note is to describe in detail the all-arthroscopic, covered microfracture and bone marrow concentrate (CMBMC) technique applied to full-thickness, focal, condylar cartilage defects.

CASE PRESENTATION

A 37-year-old man had medial joint-line pain in the left knee after landing from a jump 6 months earlier. He had no ligament laxity, and all meniscal signs were negative; weight-bearing knee radiographs also yielded negative findings. The magnetic resonance imaging scan depicted a cartilage area with inhomogeneous signal on the anterior aspect of the medial femoral condyle and a corresponding marrow edema (Fig 1). The patient gave his informed consent for an arthroscopic examination.

Surgical Technique

The patient, under spinal anesthesia, was placed supine with the left leg free. The donor site at the level of the left iliac crest was prepared and draped.

Access to the left knee joint was through standard anteromedial and anterolateral portals (Video 1). Joint inspection disclosed a 3-cm^2 cartilage lesion on the anterior aspect of the medial condyle (Fig 2A), providing the indication for a CMBMC procedure. A 2.5-mm Jamshidi needle (CareFusion, San Diego, CA) was inserted percutaneously into the iliac crest (Fig 3A); 60 mL of bone marrow blood was aspirated with 2 syringes (2 × 30 mL), each containing 4 mL of EDTA and processed with the MarrowStim Concentration Kit (Biomet, Warsaw, IN) according to the manufacturer's instructions, obtaining 3 to 4 mL of BMC (Fig 3B).

The joint was reaccessed and the lesion debrided. MFXs spaced 2 to 3 mm apart were performed with appropriate awls (Karl Storz, Tuttlingen, Germany) (Fig 2B). A bent 1.2-mm K-wire was inserted through the medial portal to measure the main lesion dimensions; these were reported on a rubber template that was then adjusted to the exact shape of the defect. A MeRG collagen membrane (Bioteck, Torino, Italy), whose side facing the joint had previously been marked with asymmetric lines with a dermographic pen to facilitate intra-articular orientation, was cut to match the defect shape (Fig 3C) and, finally, immersed in BMC until implantation (Fig 3D).

The water flow was stopped, and water was aspirated from the joint cavity. Two methods were used to gain a better view of the lesion: (1) Two large suture needles were introduced from the medial portal and driven to exit the joint superomedial and inferomedial to the portal; pulling of the sutures from outside the joint resulted in soft-tissue retraction, with a better view of the defect

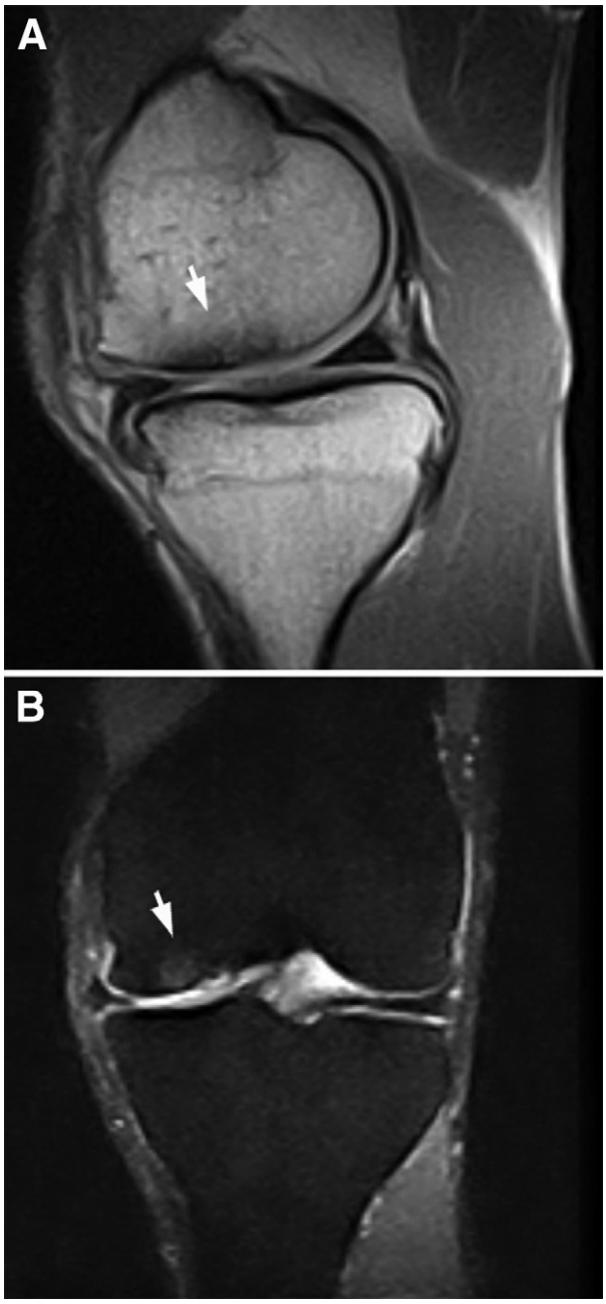

Figure 1. Preoperative magnetic resonance imaging scan of left knee. (A) The T1 sagittal section shows inhomogeneous cartilage and bone signals (arrow). (B) The T2 coronal section shows a cartilage cleft on the lateral aspect of the medial condyle and bone marrow edema (arrow).

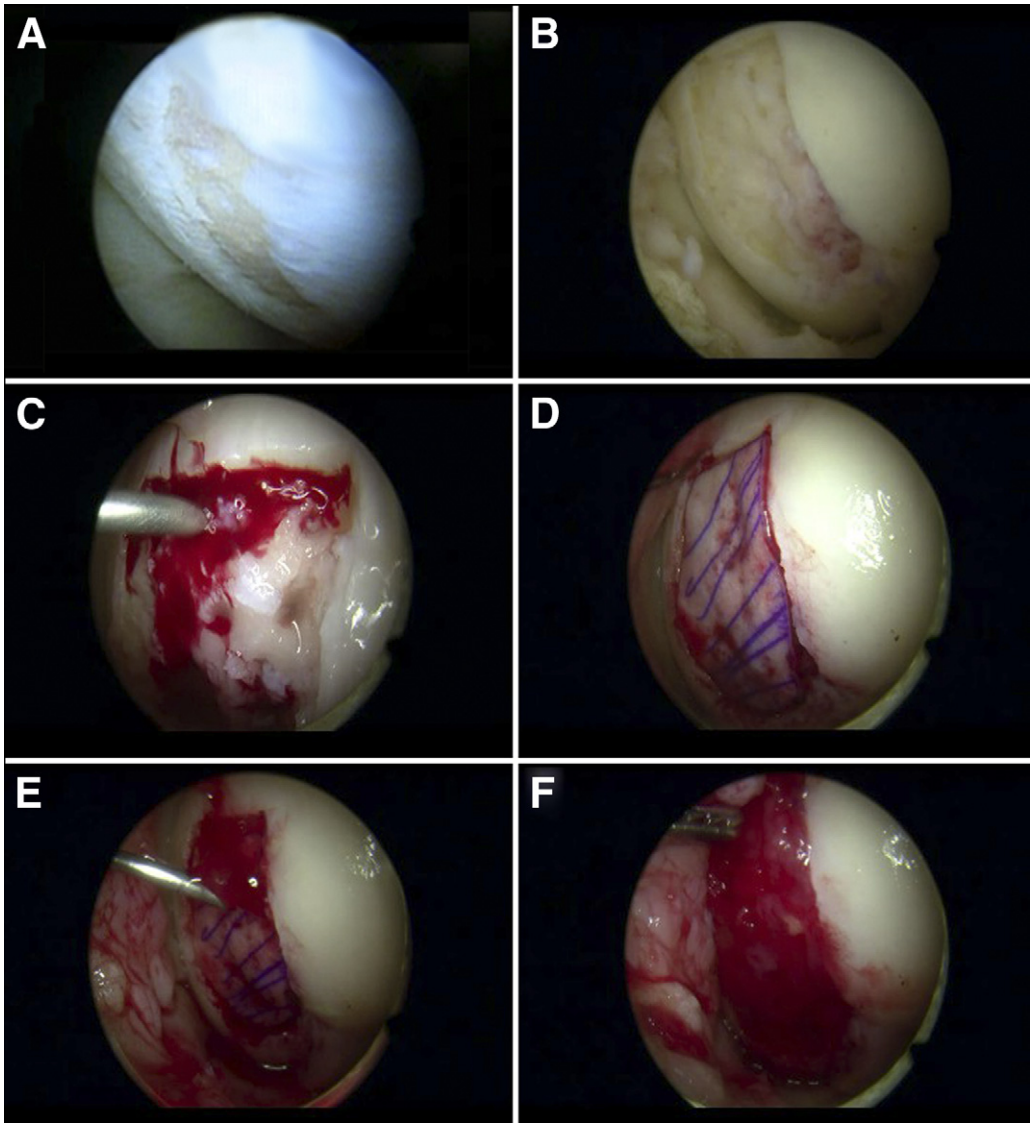

Figure 2. Arthroscopic technique. The cartilage lesion on the anterior aspect of the medial condyle is viewed from the lateral portal. (A) The cartilage defect is identified. (B) Debridement and MFX are performed. (C) A fibrin glue–BMC mixture is deposited on the defect bed. (D) The membrane is set in place with a probe. (E) The membrane is covered with the fibrin glue–BMC mixture. (F) Final appearance of the repaired defect.

(Fig 3E). (2) A carbon dioxide pump was not used, to simplify the procedure; instead, air was blown from the portal on the side of the defect by use of a 100-mL syringe, to distend the joint cavity (Fig 3F). Then, a 10:1 mixture of 1 to 2 mL of fibrin glue (Tisseal, Baxter, IL) and BMC was laid on the lesion bed with a long needle (Fig 2C). The membrane was inserted through the medial portal with a grasper and fitted into place with a probe (Fig 2D). Then, an additional 2 to 3 mL of the fibrin glue–BMC mixture was deposited on the membrane and left to congeal for 2 to 3 minutes (Fig 2E). Finally, excess mixture was removed (Fig 2F), and the knee was repeatedly flexed and extended to check membrane stability. Tips and pearls of the surgical technique are summarized in Table 1.

Clinical Results

The patient started continuous passive motion on day 5 and partial weight bearing at 3 weeks, progressing to full weight bearing at 6 weeks. At 6 months, he had no pain and was allowed to start jogging. A

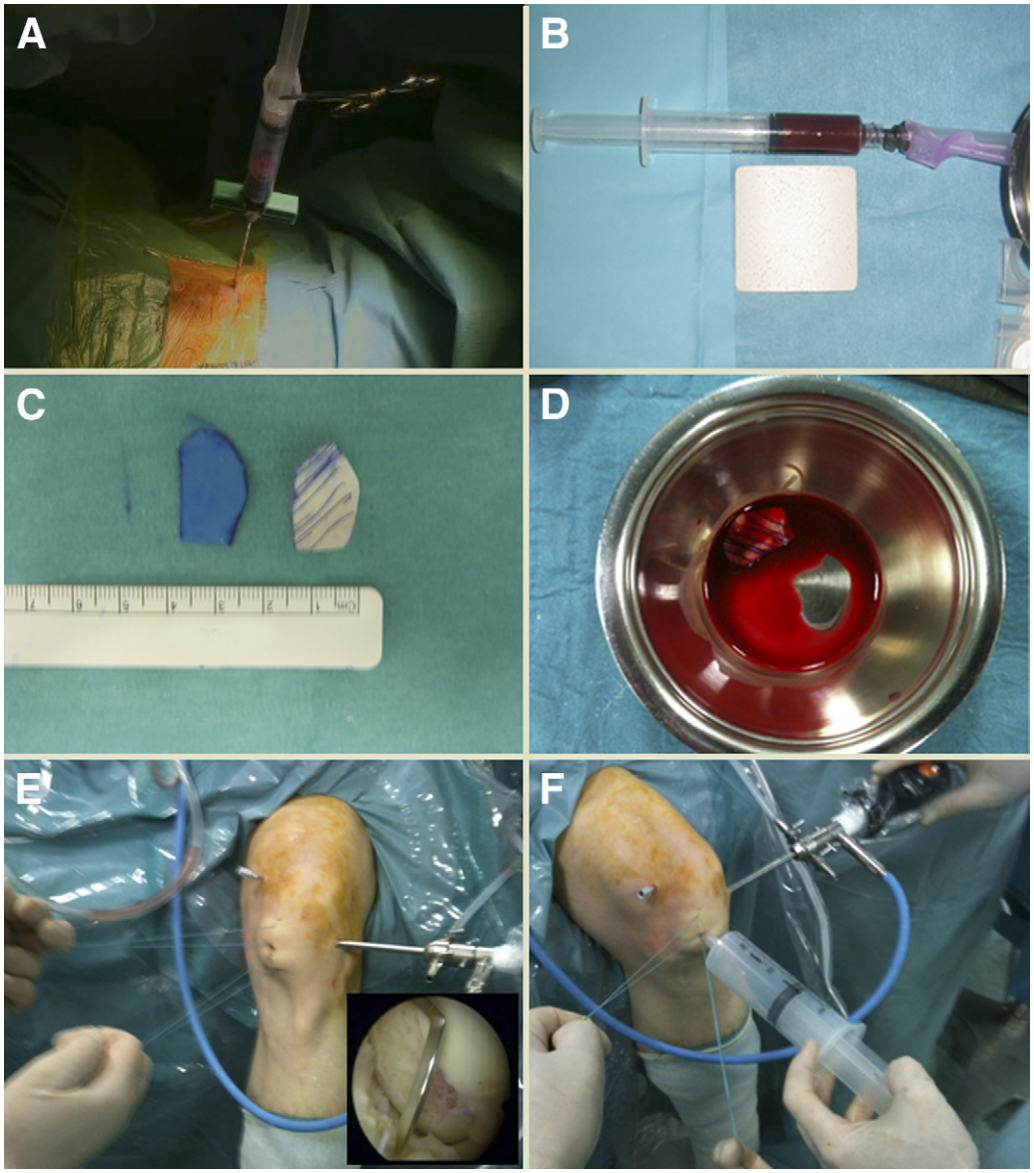

Figure 3. Marrow blood is (A) aspirated from the iliac crest with a syringe and (B) concentrated to obtain 3 to 4 mL of BMC. After shaping of the rubber template to match the defect, (C) the membrane is cut to match the lesion and (D) immersed in BMC. To improve the view of the lesion, (E) suture needles are inserted from the medial portal and pulled from outside; (F) then air is blown into the cavity with a 100-mL syringe.

magnetic resonance imaging scan at 12 months showed good defect filling with a tissue signal very similar to that of surrounding tissue, as well as no signs of bone marrow edema (Fig 4). At 24 months, the patient is still asymptomatic.

DISCUSSION

Single-stage procedures for cartilage repair combining MFX and a protective scaffold have grown in popularity in recent years. However, despite good clinical results, the quality of the regenerated tissue and the level of tissue filling are not ideal.[1,5] The addition of platelet-rich plasma to the procedure has provided good clinical outcomes but, again, incomplete tissue regeneration.[3] More recently, peripheral blood progenitor cells or cultured MSCs have been combined with MFX with or without a protective scaffold to treat knee cartilage defects.[11-13] These procedures, though safe and ef-

fective, all involve an early step for filgrastim administration and plasma apheresis or, for bone marrow blood harvesting, cell sorting and subsequent culture. The 2 steps plus autologous cell manipulation involve considerable expense. Moreover, the indication for the procedure needs to be established by diagnostic arthroscopy before the operation.

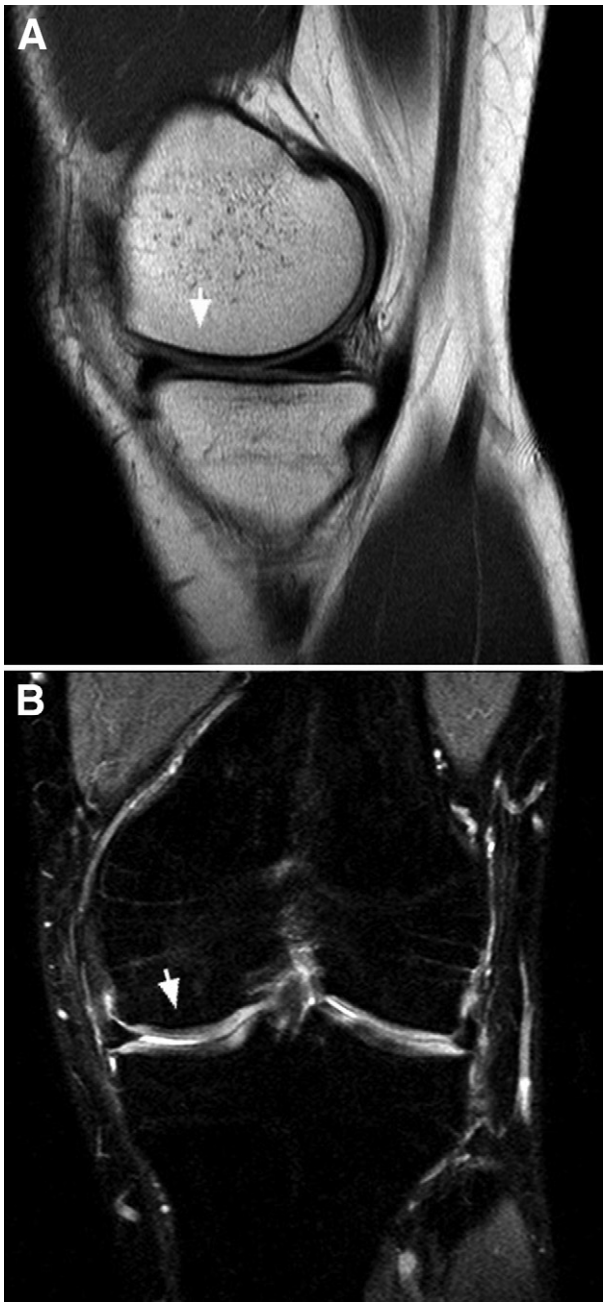

FIGURE 4. Postoperative magnetic resonance imaging scan (12 months) of left knee. (A) The T1 sagittal section shows good defect filling and slight signal hyperintensity in the anterior part of the repair area (arrow). (B) The T2 coronal section shows good defect filling and no marrow edema (arrow).

TABLE 1. *Tips and Pearls of the Procedure*

If a cartilage defect needing repair is suspected, prepare a donor site at the level of the iliac spine.
Draw marrow blood slowly to increase its cellularity and reduce fat and serum content.
Move the tip of the Jamshidi needle once or twice within the iliac bone to maximize marrow blood suction.
Prepare a vertical shoulder of the cartilage defect using a small arthroscopic osteotome.
Measure the defect precisely with bent K-wires inserted from the portal and shape a rubber template.
Mark the outer scaffold surface asymmetrically to facilitate its orientation in the joint.
Improve the view of the defect with sutures inserted from the portal and pulled from outside the joint.
Improve the view of the defect by blowing air into the cavity with a 100-mL syringe.
Dilute the fibrin glue 10:1 with BMC to extend manipulation time.

Recent studies have indicated that the addition of BMC to single stage procedures for knee cartilage defects could enhance the cartilage regeneration potential.[8,9] The CMBMC technique has already proved to have the potential to regenerate hyaline-like cartilage in lesions larger than 2 cm^2.[14] The technique, which has never been described in detail before, is a single-stage procedure that can be performed during the diagnostic arthroscopy. Bone marrow blood is harvested with minimal morbidity and quickly concentrated by an inexpensive procedure. The all-arthroscopic technique is reproducible and allows short rehabilitation times. Advantages and limits of the procedure are summarized in Tables 2 and 3, respectively.

In summary, the CMBMC technique proved to be safe and effective and can be adopted with an all-arthroscopic approach to treat lesions larger than 2 cm^2. The clinical outcomes of a patient group treated

TABLE 2. *Advantages of CMBMC Technique*

No need for previous diagnostic arthroscopy
No need for watertight suture
No need for circumferential stitches[3] or single-pin[2,7] scaffold fixation
No need for carbon dioxide pump

TABLE 3. *Limits of CMBMC Technique*

CMBMC takes about 20-30 min longer than the respective original single stage procedure.
Lateral femoral condyle lesions are more difficult to treat than medial femoral condyle lesions.
Lesions larger than 3-4 cm^2 are more difficult to treat than smaller-sized lesions.
Morbidity related to the percutaneous marrow blood harvest on the iliac crest is possible.

with this technique will be reported in a separate article.

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