Technical Note

All-Arthroscopic Matrix-Associated Autologous Chondrocyte Implantation for a Trochlear Defect

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Abstract: Matrix-associated autologous chondrocyte implantation (MACI) is a 2-step technique designed to treat symptomatic full-thickness articular cartilage defects of the knee. In this technique article, MACI (autologous cultured chondrocytes on porcine collagen membrane) is used to treat a femoral trochlear defect of the knee. Treating a defect with this technique leads to improved clinical outcomes by restoring the native chondral surface architecture and biomechanics of the knee. In addition, it has the potential to prevent or delay further progressive degeneration of the joint. It is a 2-stage procedure consisting of an initial arthroscopic cartilage biopsy, followed by 4 to 6 weeks of in vitro chondrocyte expansion and, finally, re-implantation. We recommend performing the MACI procedure arthroscopically for the second stage to treat a femoral trochlear defect. During the second surgical procedure, we examine and prepare the recipient site, followed by graft introduction in an all-arthroscopic manner via dry scoping, secured by a thin layer of fibrin glue.

Articular cartilage injuries of the knee are common and often result in pain, dysfunction, and decreased quality of life. An estimated 52.5 million adults (22.7%) in the United States were told by a physician that they had some form of cartilage damage and/or arthritis.[1] Nonoperative management has been shown to improve symptoms and quality of life for many of these patients. However, symptomatic articular cartilage defects of the knee have the potential to alter joint reaction forces, produce a widespread inflammatory response, and lead to progressive joint degeneration if left untreated.[2,3] With the absence of a blood supply and innervation, articular cartilage has highly restricted self-healing properties, thus often requiring surgical treatment.[4] Furthermore, in select patients with symptomatic defects, surgical intervention has the potential to prevent or delay progressive degeneration.[5] Matrix-associated autologous chondrocyte implantation (MACI) is a 2-step technique designed to treat full-thickness articular cartilage defects of the knee. The first step involves arthroscopy to obtain a cartilage biopsy specimen from a non–weight-bearing area of the knee, followed by cultivation and expansion of the chondrocytes within a type I–type III collagen membrane under laboratory conditions.

This procedure has become a popular technique of choice to treat cartilage defects in the patellofemoral compartment as a result of the favorable outcome studies and the ease with which the complex surface architecture can be re-created. In fact, autologous chondrocyte implantation (ACI) was determined to be the most common restoration technique of the patellofemoral joint according to a recent systematic review.[6] Similarly, another systematic review that included 42 studies reported that ACI was the most performed technique for patellofemoral cartilage lesions.[7] The most common implantation approach involves an open arthrotomy of the knee, but arthroscopic techniques have been described.[8-10] Theoretical advantages of an all-arthroscopic technique compared with the traditional open technique include decreased pain, swelling, and arthrofibrosis.[9] The applicability of this all-arthroscopic technique

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includes femoral trochlear, tibial, and select femoral condylar defects. In this case, the trochlear location allows for a directly accessible trajectory by a cannula aided by patient positioning and gravity.

Patient Evaluation and Treatment Algorithm

Joint pain, stiffness, swelling, and locking are commonly associated with cartilage defects of the knee. Patients may report a traumatic injury, but it is not uncommon for patients to experience an insidious onset of vague discomfort and swelling without a history of trauma. After a detailed history is obtained from the patient, a physical examination is performed to evaluate for the presence of an effusion, assess the range of motion, and identify any potential ligamentous instability. Routine radiographic studies include standing anteroposterior, lateral, Merchant, and 45° flexion posteroanterior views. For patients with a known or suspected chondral defect, full limb-length radiographs are obtained to determine mechanical alignment. Magnetic resonance imaging is the advanced imaging modality of choice to evaluate the articular cartilage and assess for subchondral bone marrow edema. Additionally, computed tomography can be performed to further evaluate the fine anatomic detail of subchondral bone. The magnetic resonance imaging and/or computed tomography scans should be carefully reviewed to assess for patellofemoral malalignment by determining the tibial tubercle—to—trochlear groove distance.

Nonoperative measures in the form of rest, activity modification, anti-inflammatory medications, injections, and/or physical therapy are the initial management for most articular cartilage lesions. However, surgical intervention should be considered for patients whose injuries continue to be symptomatic despite conservative care. Age, activity level, patient expectations, defect size, and associated injuries are all important factors in determining whether someone is a surgical candidate. Patients who are considered surgical candidates must understand that many of the cartilage-restoring procedures require extensive rehabilitation and that they will be unable to return to activities for extended periods. Surgical options for symptomatic full-thickness articular cartilage defects include arthroscopic debridement, drilling, microfracture, osteochondral autograft transfer, osteochondral allograft transplantation, and MACI. The preferred treatment method for patellofemoral defects of the senior author (B.J.C.) is the MACI technique, and an all-arthroscopic technique for a femoral trochlear defect will be described in detail (Video 1). Our indications and contraindications are listed in Table 1.

Table 1. Indications and Contraindications

Indications
Isolated full-thickness articular cartilage defects
No generalized degenerative changes
Contraindications
Significant generalized osteoarthritis
Inflammatory arthritis
History of septic joint
Significant ligamentous instability or malalignment not addressed with concomitant surgery
BMI > 35
Nicotine use

BMI, body mass index.

Surgical Technique

Step 1: Positioning and Preoperative Examination

The patient is positioned supine on a standard operating table. General anesthesia is administered. A sequential compression device is placed on the contralateral lower extremity, and the operative extremity is examined under anesthesia. Full passive range of motion is demonstrated, along with no ligamentous instability. A thigh tourniquet is placed, followed by preparation and draping of the lower extremity using the standard sterile technique. Next, the tourniquet is insufflated to 250 mm Hg.

Step 2: Initial Incision and Diagnostic Arthroscopy

After preoperative preparation, an anterior-inferior lateral incision is made. Afterward, a trocar is used to further advance into the patellofemoral joint. Once infiltration is successful, diagnostic arthroscopy is performed. On examination, a full-thickness chondral defect of the femoral trochlea is observed (Fig 1). No abnormality of the patella is detected. An anteromedial portal is then established under direct visualization, ensuring not to injure the anterior horn of the medial meniscus. After insertion of the probe, the medial compartment shows no evidence of chondral or meniscal abnormality. The anterior and posterior cruciate ligaments are intact, and the lateral compartment shows no indications of chondral deterioration or meniscal abnormality. The arthroscope is then taken back into the patellofemoral joint to further evaluate and prepare the cartilage defect. On further assessment of the chondral defect, it is concluded that the defect is full thickness, centrally located within the proximal trochlea, and surrounded by healthy cartilage borders (Fig 2).

Step 3: Chondral Defect Preparation and MACI Implantation

Ring curettes are used for chondral defect preparation. Unhealthy damaged cartilage is removed, as well as the calcified layer, and stable borders are created (Fig 3). An 8-mm shoulder cannula is then introduced through the medial portal. The senior author prefers to

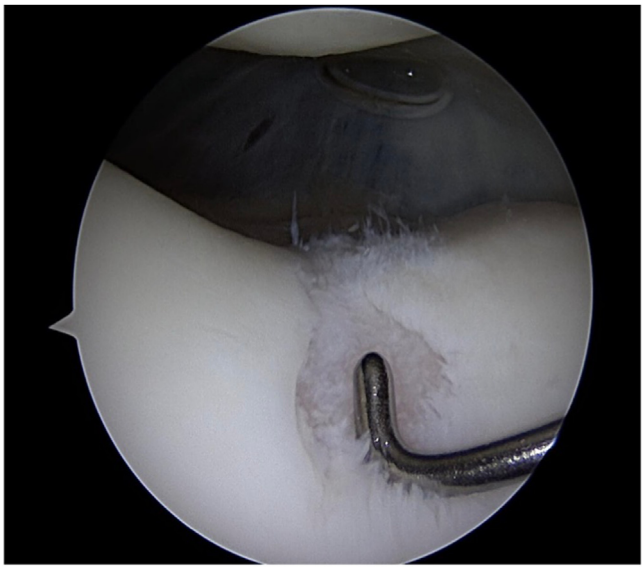

Fig 1. Full-thickness femoral trochlear defect with probe measuring 1 cm × 2 cm, viewing from standard anterior-inferior lateral portal. Right knee, positioned supine.

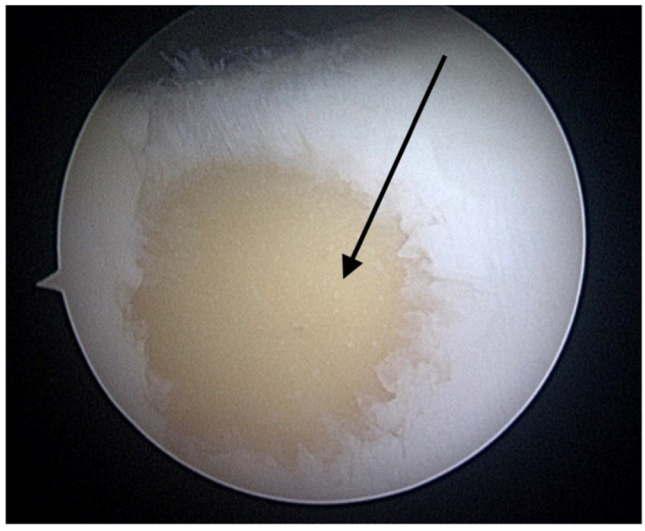

Fig 3. Ring curette debridement has been performed to stable borders and down to subchondral bone (arrow), viewing from standard anterior-inferior lateral portal with standard 30° arthroscope and ring curette instrumentation through anterior-inferior medial portal. Right knee, positioned supine.

remove the inner portion of the shoulder cannula with a surgical scalpel to ensure direct access to the inner joint in order to avoid pressure and minimize manipulation of the MACI implant. A template of the defect with the correct size and shape is created using a cut piece of Esmarch material (Softex Industrial Products, Kolkata, India) attached to a No. 1-0 Vicryl suture (Ethicon, Raritan, NJ) (Fig 4). It is important to note that this is an off-label use of the Esmarch material because it is not designed to be placed into the knee joint. It is precisely contoured to the diameter of the lesion and can be shuttled in and out of the knee through the cannula with the help of an arthroscopic grasper and tension on the attached suture. The MACI implant is then opened and placed on the back table using a sterile technique. It is trimmed to the appropriate size and shape based on the template created earlier. On completion of this step, the remainder of the case is performed via dry scoping in the absence of irrigation. The subchondral region is dried using a narrow-diameter suction device as well as a small peanut sponge introduced through the cannula with an arthroscopic grasper. This is followed by the placement of a 0.045-mm Kirschner wire within the center of the defect through the cannula and a thin layer of fibrin glue at the base using an 18-gauge spinal needle attached to the Tisseel fibrin glue applicator (Baxter, Glenview, IL) (Fig 5). The appropriately shaped and contoured MACI implant is then delivered through the cannula by piercing the center of the implant with the Kirschner wire and gently sliding it to the base of the defect with the help of an arthroscopic grasper. The senior author does not always use the Kirschner wire to aid in membrane placement but does use it on occasion based on access and the location of the defect within the knee. Pressure is applied using the small peanut sponge introduced through the cannula with an arthroscopic grasper. A thin layer of fibrin glue is added around the perimeter thereafter (Fig 6). The knee is then aggressively ranged, and the arthroscope is reintroduced. The membrane of the defect is stable and in an excellent position without evidence of displacement (Fig 7). After confirmation of the membrane's stability, the tourniquet is deflated. The portal sites are then closed in an interrupted fashion using No. 3-0 nylon. Sterile dressings are applied in the form of a petroleum-based sterile

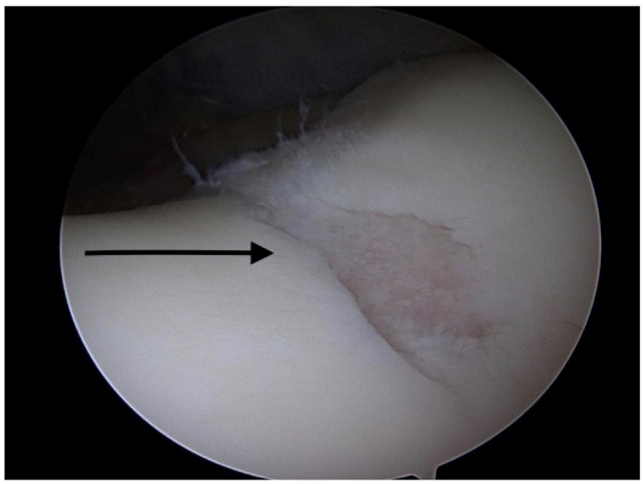

Fig 2. Full view of femoral trochlear defect (arrow) without probe from standard anterior-inferior lateral portal with standard 30° arthroscope. Right knee, positioned supine.

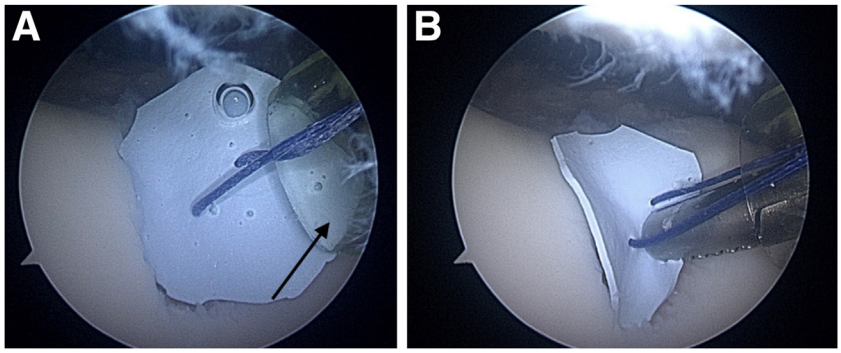

Fig 4. (A, B) Off-label use of Esmarch material for accurate sizing of full-thickness cartilage lesion. It is precisely contoured to the diameter of the lesion and can be shuttled in and out of the knee through the cannula with the help of an arthroscopic grasper and tension on the attached suture. The arrow indicates an 8-mm shoulder cannula introduced through the medial portal. The senior author prefers to remove the inner portion of the shoulder cannula with a surgical scalpel to ensure direct access to the inner joint in order to avoid pressure and minimize manipulation of the matrix-associated autologous chondrocyte implant. Right knee, positioned supine.

mesh dressing, 4 × 4 inch gauze, and a gentle foot to knee compression wrap. The patient is also placed in a hinged knee brace. Our technical pearls and pitfalls are summarized in Table 2.

Rehabilitation Protocol

The procedure results in a same-day discharge. After the surgical procedure, the patient is allowed weight bearing as tolerated with the knee brace locked in extension. Immediate isometric quadriceps exercises are initiated, along with passive range of motion to 90°. Continuous passive motion from 0° to 30° is recommended for 6 hours a day during the first 2 weeks, followed by 0° to 60° at 2 weeks and 0° to 90° at 4 weeks. Formal physical therapy is initiated within 2 to 3 days of surgery.

Discussion

MACI is indicated for patients with isolated, symptomatic full-thickness cartilage defects of the knee joint in whom nonoperative treatment has failed and who have no significant osteoarthritis. Migliorini et al.[11] conducted a systematic review to evaluate clinical outcome differences between mini-open and all-arthroscopic MACI delivery and found similar Lysholm and International Knee Documentation Committee scores at mid-term follow-up (24-60 months). Furthermore, in a recent systematic review, Colombini et al.[12] showed that MACI sustained clinical improvements for up to 15 years, allowing arthroplasty to be delayed with improved patient-reported outcomes and quality of life. Hevesi et al.[13] described an open arthrotomy technique using a longitudinal incision measuring 6 to 8 cm to prepare the recipient site on the femoral trochlea, followed by securing the MACI patch with fibrin glue. To the contrary, we present an all-arthroscopic technique aided by dry scoping and an 8-mm graft-delivering cannula. We have shown in our technique that an isolated femoral trochlear lesion, which is gravity dependent, is suitable for all-arthroscopic graft delivery and fixation, and this is consistent with the findings and summary of Cortese et al.[14] In a 2022 systematic review, Migliorini et al.[15] showed equivalent Tegner Activity Scale scores regardless of membrane fixation technique (glued vs glued and suturing vs no fixation). In addition, the arthroscopic technique is our preferred method to treat symptomatic tibial chondral defects owing to the difficulty with open access and visualization of this area of the knee.

Several authors have described arthroscopic ACI techniques.[8-10] Erggelet et al.[8] described a technique that uses a guidewire placed through femoral bone combined with resorbable sutures that are used as pulley slings to bring the implant into the joint. Ebert et al.[9] published their technique involving the use of a large-bore 8-mm arthroscopic cannula to allow

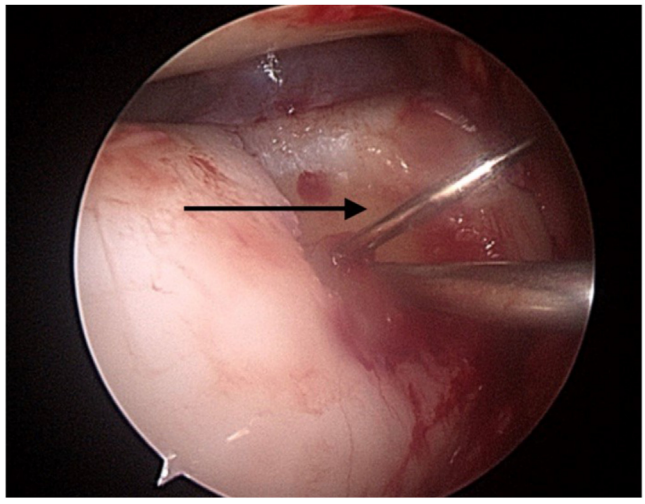

Fig 5. Dry scoping. The arrow indicates a 0.045-mm Kirschner wire placed within the center of the lesion. An 18-gauge spinal needle attached to the Tisseel applicator is used to deliver fibrin glue after the subchondral region has been dried using a narrow-diameter suction device, as well as a small peanut sponge introduced through the cannula with an arthroscopic grasper. Right knee, positioned supine.

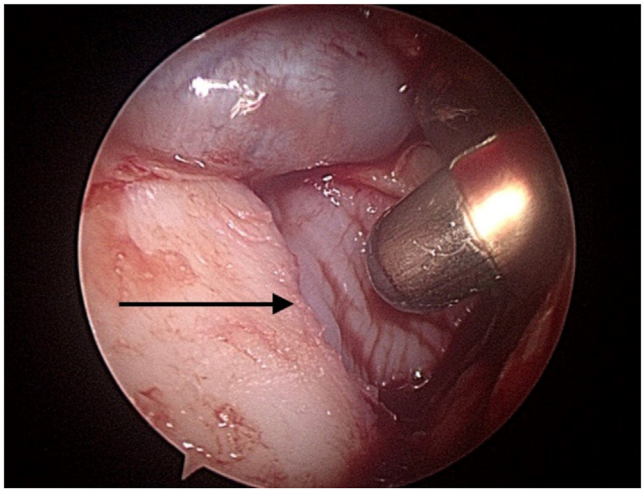

Fig 6. Pressure is applied using the small peanut sponge (not shown) introduced through the cannula with an arthroscopic grasper. A thin layer of fibrin glue is added around the perimeter thereafter. The arrow indicates the newly applied membrane with no sign of proud positioning. Right knee, positioned supine.

multiple passes of the graft in and out of the joint for fine-tuning of the size and shape of the implant. However, studies have suggested that increased manipulation and handling of the membrane can result in chondrocytes lifting off of the membrane, as well as increased chondrocyte cell death.[16] As a result, we believe that our technique allows for minimal manipulation of the implant by passing the Esmarch material in and out of the joint to achieve the final implant size prior to 1-time passage and manipulation. In conclusion, we have shown the safety and effectiveness of all-arthroscopic delivery and fixation of MACI graft to treat a gravity-friendly isolated femoral trochlear full-thickness cartilage lesion.

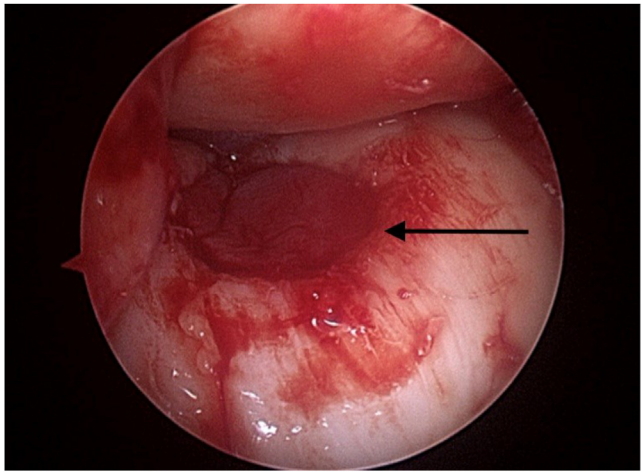

Fig 7. Stable membrane (arrow) after ranging knee, with no sign of movement or displacement with intraoperative knee motion. Right knee, positioned supine.

Table 2. Pearls and Pitfalls

Pearls
Dry scoping during application of membrane; use of topical TXA into joint to facilitate clear dry scope environment
Use of 8-mm shoulder cannula as conduit for graft
Care taken not to violate subchondral bone when using ring curette
Careful examination of graft behavior once MACI implant secured, while scope is kept in knee, to avoid traumatic re-entry with scope cannula
Pitfalls
Mis-sizing of graft
Proud placement of graft
Not correcting patellofemoral malalignment when indicated or needed

MACI, matrix-associated autologous chondrocyte implantation; TXA, tranexamic acid.

Disclosures

The authors report the following potential conflicts of interest or sources of funding: B.J.C. is a paid consultant for DePuy Mitek (A Johnson & Johnson Company) and is a paid speaker for Vericel. All other authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

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