



Treatment of Patellar Chondral Lesions With Concomitant Matrix-Induced Autologous Chondrocyte Implantation, Medial Patellofemoral Ligament Reconstruction, and Tibial Tubercle Osteotomy

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Abstract: The US Food and Drug Administration approved matrix-induced autologous chondrocyte implantation (MACI) for use in the United States in 2016, and it has proven to be an effective treatment for articular cartilage defects in the knee. Concomitant patellar stabilization and realignment procedures, such as tibial tubercle osteotomy (TTO) and medial patellofemoral ligament (MPFL) reconstruction, are often performed with MACI to prevent further damage to the knee and to sustain the integrity of the cartilage repair. This Technical Note aims to describe MACI in the patella with concomitant patellar stabilization and realignment and to provide a treatment algorithm for when various simultaneous procedures are indicated. The authors believe that correction of patellar malalignment and instability is crucial to the success of cartilage repair procedures. Therefore, we recommend that TTO and MPFL reconstruction be performed with MACI procedures of the patella when the anatomic pathology and pertinent patient history, such as articular cartilage defects with patellar instability and abnormal patellar alignment, are present.

Surgeries to restore articular cartilage defects in the knee are commonly performed in the United States.¹ It is essential to treat these defects, especially in the adolescent population, as they can lead to the progression of osteoarthritis in the knee.^{2,3} Recovery can be difficult in these injuries, though, as cartilage is avascular and has low healing potential.⁴ Despite this drawback, several procedures have proven to be effective, including chondroplasty, osteochondral allograft, osteochondral autograft transplantation, microfracture, and, more recently, matrix-induced autologous chondrocyte implantation (MACI).⁵

The US Food and Drug Administration approved MACI for use in the United States in 2016, and it has proven to be an effective treatment for articular cartilage defects in the knee.⁶⁻⁸ It is a 2-phase procedure that requires an initial biopsy of chondrocytes from the knee. After the patient's chondrocytes are seeded onto a porcine membrane, implantation in the knee allows for restoration of the articular surface. Indications for MACI are determined preoperatively by assessing the lesion using magnetic resonance imaging (MRI) and arthroscopy. MACI has no lesion size restrictions, making it a viable option for many patients with focal chondral defects.⁹

A recent multicenter study we conducted that included 145 patients with patellar defects across 10 surgeons showed a mean defect size of 4.68 cm². Patellar lesions were mostly solitary (68.5%), with multifocal lesions being less common (31.5%). This cohort was predominantly female (69.8%), with a mean age of 32.08 years.

However, treatment of the defect is often insufficient in these patients, as their initial injury stems from underlying patellar instability or malalignment. Numerous anatomic and physiologic abnormalities can contribute

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to chondral defects in the knee, including patella alta, lateral tilt, medial patellofemoral ligament insufficiency, and trochlear dysplasia.¹⁰ Concomitant patellar stabilization and realignment procedures are often performed with MACI to prevent further damage to the knee and to sustain the integrity of the cartilage repair. Most commonly, these procedures include medial patellofemoral ligament (MPFL) reconstruction, lateral lengthening, and tibial tubercle osteotomy (TTO). Indication for these surgeries depends on numerous factors, including patient age, alignment, instability, and injury severity.

This Technical Note aims to describe MACI in the patella with concomitant patellar stabilization and realignment and to provide a treatment algorithm for when various concomitant patellar stabilization and realignment procedures are indicated.

Technique

Preoperative

During the initial clinical assessment of the patient, an MRI is conducted to assess lesion size, ligament insufficiency, patellar alignment, and other abnormalities such as meniscal pathology or trochlear deformities. Patients with articular chondral defects greater than 2 cm² are candidates for MACI, whereas defects with significant subchondral bone involvement may be better suited to an osteochondral allograft. For patients

with patellar instability or a history of patellar dislocation, the MPFL can be assessed on MRI. A patient with a torn MPFL is always indicated for MPFL reconstruction and cartilage repair. Assessment of patellar alignment and height is also important to evaluate, as this can predispose individuals to cartilage defects of the knee.¹¹⁻¹³ The Insall-Salvati ratio¹⁴ and Caton-Deschamps Index¹⁵ can be used to quantify the patellar height on MRI (Fig 1A). An Insall-Salvati ratio (ratio of the patellar tendon to the maximum length of the patella) or a Caton-Deschamps Index (ratio of the length between the anterior angle of the tibial plateau to the most inferior aspect of the patellar articular surface) ≥ 1.2 indicates patella alta in the patient. To evaluate the patellar alignment, the distance between the tibial tubercle and the trochlear groove (TT-TG) can be measured on MRI or computed tomography (Fig 1B). A TT-TG >15 mm on MRI predisposes the patient to patellar instability,¹⁶ which should also be addressed if this finding exists. To treat underlying patella alta or malalignment, a TTO can be performed. A distalization technique will address the patient's patella alta, and anteromedialization will realign the patella in the trochlear groove.

Stage 1: Biopsy and Chondroplasty

Arthroscopy portals are established, beginning with an anterolateral portal and an anteromedial portal made under direct visualization. An oscillating shaver is

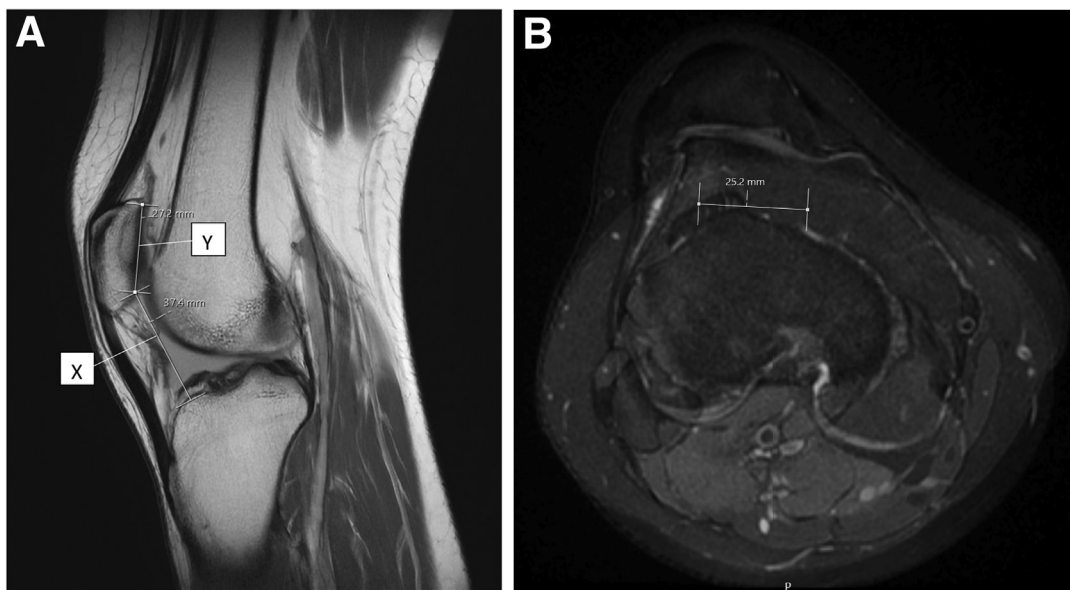


Fig 1. (A) A slice of a sagittal view of magnetic resonance imaging (MRI) of a right knee. The measurement lengths represent the Caton-Deschamps Index (CDI), which is the ratio of (X) the length from the anterior angle of the tibial plateau to the most inferior aspect of the patellar articular surface and (Y) the length of the patellar articular surface. $CDI \geq 1.2$ indicates patella alta in the patient. This patient has a CDI of $37.4/27.2 = 1.375$. (B) Two superimposed axial slices from MRI of a right knee. The measurement taken is of the distance between the tibial tubercle and the trochlear groove (TT-TG). A TT-TG of greater than 15 mm predisposes the patient to patellar instability. This patient has a TT-TG of 25.2 mm and thus should be indicated for patellar realignment.

used to debride the chondral defect. A cartilage biopsy is then taken with a gouge from the lateral aspect of the notch and placed in Vericel culture medium (Vericel). The edges of the biopsy site are then smoothed with a shaver.

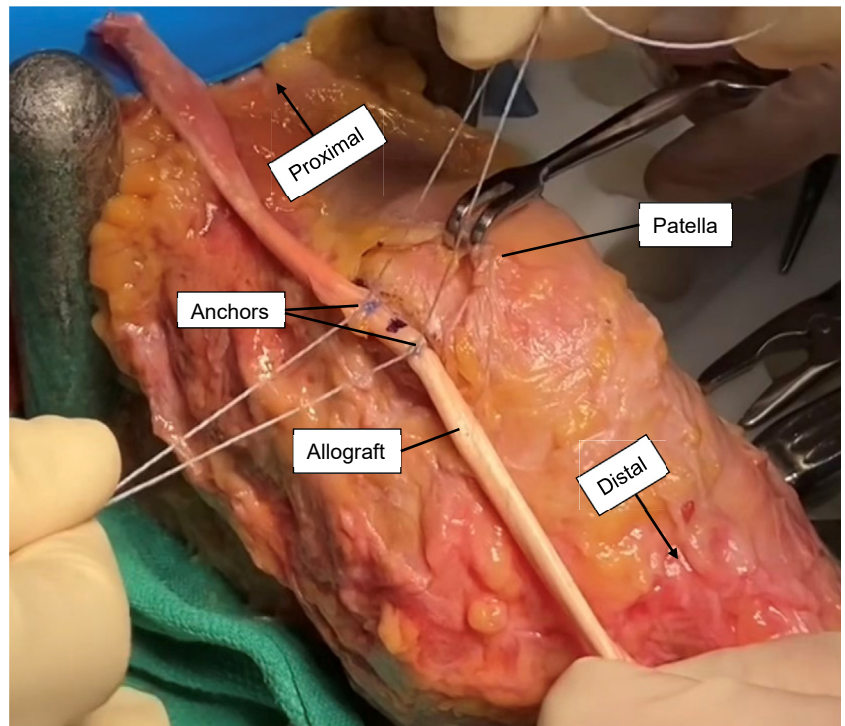
Stage 2: MACI Implantation, TTO, and MPFL

A diagnostic arthroscopy is only performed at this stage if the patient has new trauma or new symptoms. In this case, a loose body is removed, and the knee is assessed for new pathology. The limb is then exsanguinated with an Esmarch bandage, and the tourniquet is inflated to 250 mm Hg. Using a lateral incision, the MPFL reconstruction is initiated, during which the patella is retracted laterally, and a tiny medial parapatellar arthrotomy is then utilized ([Video 1](#)). Then, the layer medially is found between the capsule and retinaculum, and a Bovie is used to remove the soft tissue from the superior half of the patella, and two 1.8 Q fix anchors (Smith & Nephew) are placed at approximately the midpoint of the patella and 8 to 10 mm proximally ([Video 1](#)). A gracilis allograft is then marked at the midpoint and tied down with the sutures from the anchors ([Fig 2](#)). Attention is then turned to the tibial tubercle osteotomy. An approximately 30° to 60° shingle is free cut depending on the TT-TG ([Fig 3](#)). If a patient has significant patella alta, 0.8 to 1.2 cm of bone is removed, and a corresponding sized Evans wedge (MTF Biologics) is placed proximally ([Fig 4](#)). This is secured with two 3.5-mm screws utilizing a lag

technique through the tibial tubercle ([Video 1](#)). In the event of poor purchase of either screw, a third 3.5-mm screw can be added proximally. Fluoroscopy is used to confirm the screw length and reduction of the shingle.

A lateral lengthening approach is utilized, dividing the iliotibial band fascia from the capsule and, at the end of the case, repairing the fascia to the capsule in around 45° of flexion to allow the patella to sit centrally in the trochlea. The lesion is prepped with a scalpel and curette while the MACI is sized with a cookie cutter on the back table. Care should be taken to ensure the defect does not bleed when preparing the defect ([Fig 5](#)). The cookie cutter's size depends on the size of the chondral defect. A guidewire is then placed at the sulcus between the medial epicondyle and the adductor tubercle ([Fig 6](#)), and isometry of the MPFL graft is checked through a full range of motion. Fluoroscopy is used to confirm the placement of this tunnel. A tunnel is drilled to match the size of the graft (usually 5-6 mm) to a depth of 30 mm. A cocktail of local anesthetic is then placed into the defect. The MACI graft is then glued into the defect with Tisseel (Baxter International) placed at the periphery and held in place for 3 minutes ([Fig 7](#)). The patella is then relocated, and the knee is ranged several times from 0° to 90°. The integrity of the graft is then inspected once more. This technique can be used multiple times if multiple chondral defects are present in the knee. If the lesion is small, foil can be cut to size the lesion and prepare the graft without using the cookie cutter.

Fig 2. A left cadaver knee in the supine position. There are two 1.8 Q fix anchors (Smith & Nephew) placed at approximately the midpoint of the patella and 8 to 10 mm proximally. A gracilis allograft is shown, with the marking at the midpoint of the tendon, tied down by the sutures from the anchors. This will serve as the patellar fixation for the medial patellofemoral ligament allograft.



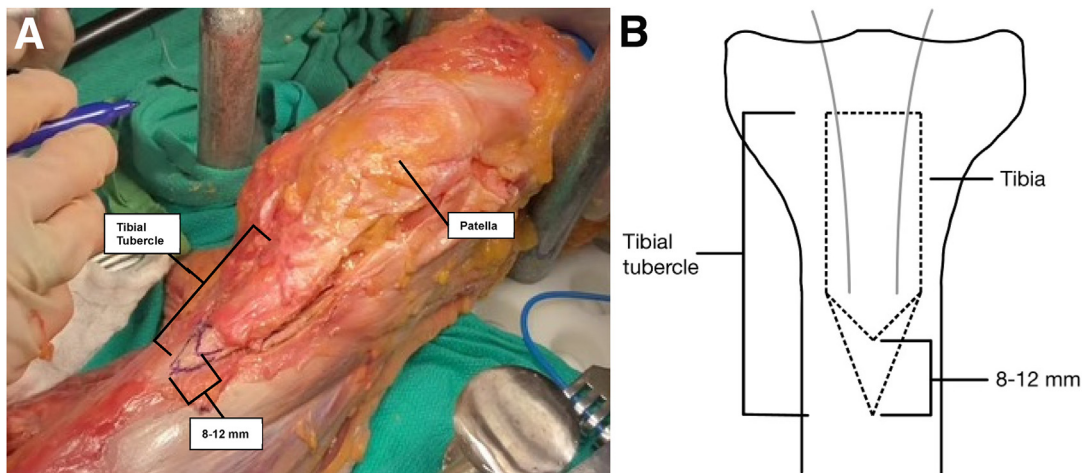


Fig 3. (A) A left cadaver knee in the supine position. The distal aspect of the tibial tubercle has been outlined for a chevron osteotomy with a marking pen. The distance between the vertices of the chevron osteotomy should measure 8 to 12 mm. This allows for movement of the tibial tubercle to correct the patient's patellar malalignment, which will subsequently be fixated with two 3.5-mm screws distally. (B) An illustration of an anterior view of the proximal tibia. The dotted line shows the outline of the cuts for the tibial tubercle osteotomy. The distal portion shows a chevron osteotomy with 8 to 12 mm between the vertices of the cuts. This allows for movement of the tibial tubercle to correct the patient's patellar malalignment, which will subsequently be fixated with two 3.5-mm screws distally.

The MPFL is then passed and secured into the femoral tunnel with the TightRope RT (Arthrex) after whipstitching the 2 ends of the gracilis with a 2-mm FiberTape suture (Arthrex) and securing the button

on the anterolateral femur, as seen in the last step of [Video 1](#). The patella is then examined for end point in full extension plus 30° to confirm that full knee range of motion is achievable ([Video 1](#)). After the closure of

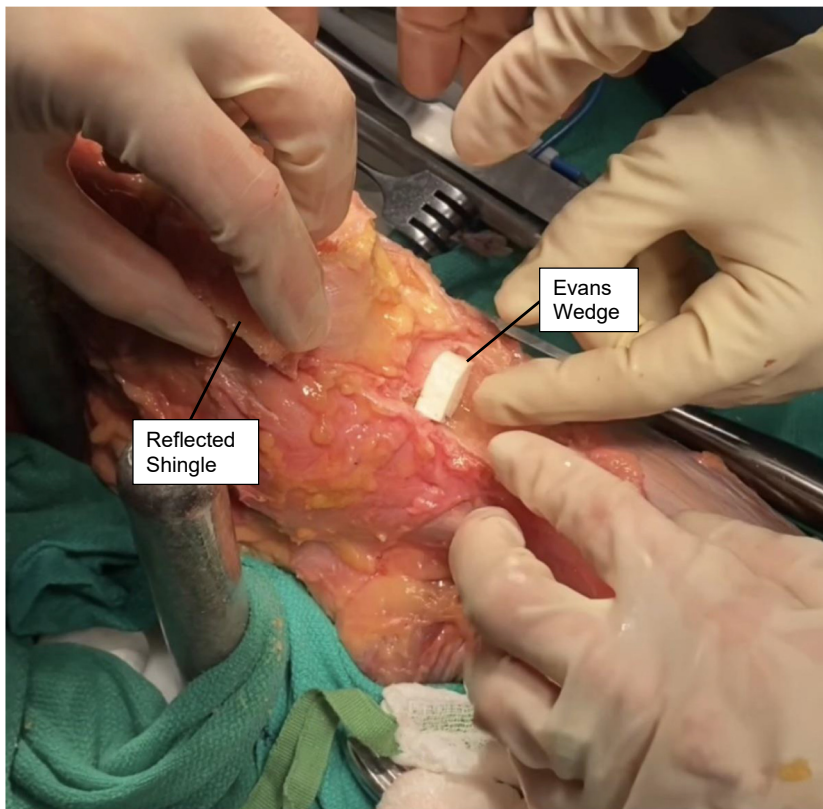


Fig 4. A left cadaver knee in the supine position. A shingle has been cut for the tibial tubercle osteotomy and is reflected proximally. An Evans wedge (MTF Biologics) is shown placed proximally in the groove left behind by the shingle. The Evans wedge will improve stability of the tibial tubercle osteotomy, correcting for patellar malalignment.

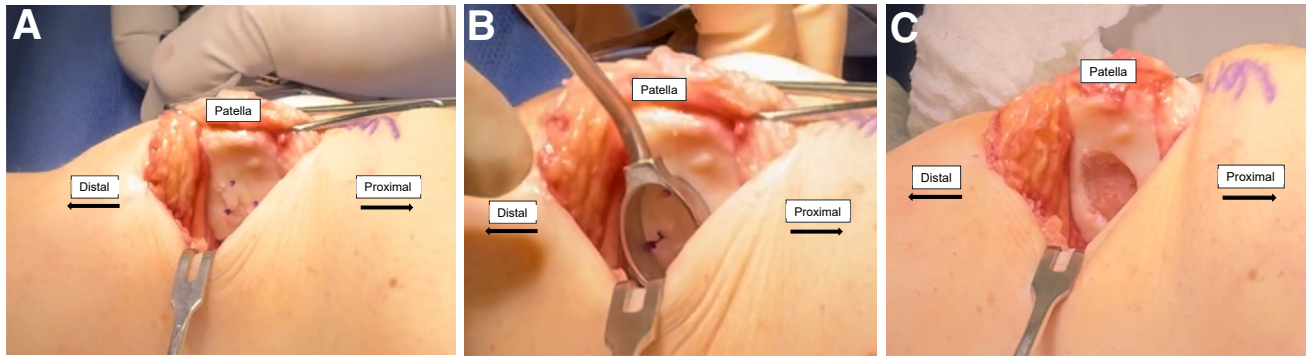


Fig 5. (A) A patient's left leg in the supine position. The everted patella is shown through a lateral arthrotomy. The patellar defect has been outlined with 3 dots made with a sterile marking pen. (B) The cookie cutter is being used to ensure that the outlined dots made with the marking pen are contained within the borders of the instrument. This ensures that the matrix-induced autologous chondrocyte implantation (MACI) graft that is cut will fill the entirety of the chondral defect. Pressure is applied to the cookie cutter to outline the area to be debrided on the patella for the MACI graft. (C) Image of the patella after the scalpel and curette have been used to debride the defective cartilage. The imprint of the cookie cutter is used as an outline to maximize continuity between the defect and the MACI graft. Care must be taken to ensure that the defect is not debrided to the point of bleeding. At this point, the MACI graft can be placed into the defect.

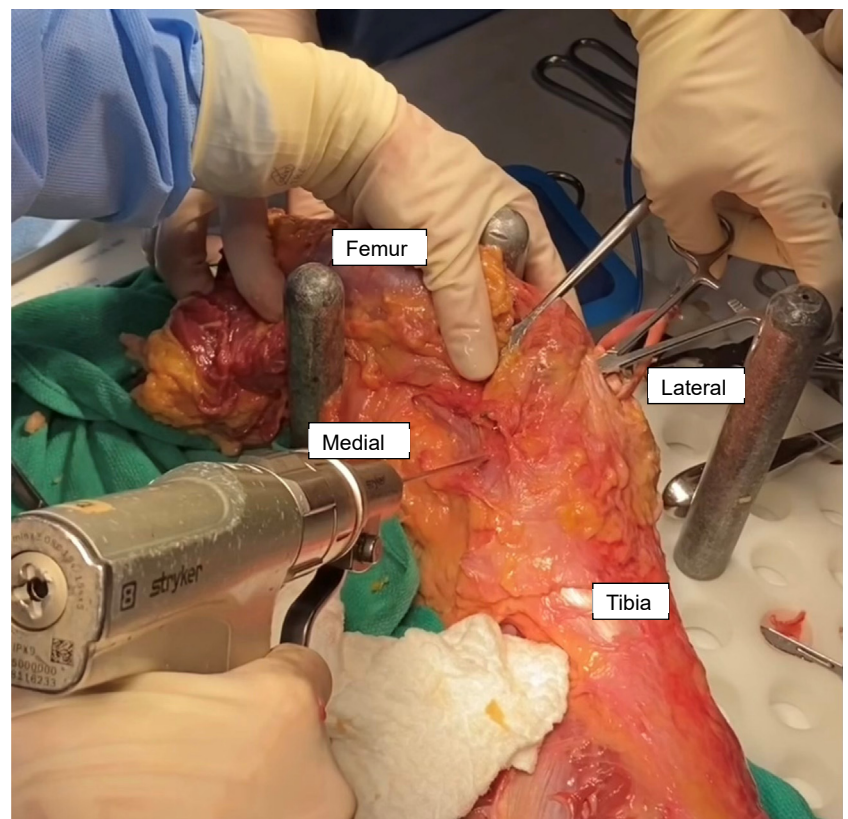
incisions, the patient is placed in a locked knee brace in full extension before they leave the operating room.

Postoperative Care

During the first 4 to 6 weeks, the patient is non-weightbearing and should use crutches to ambulate

(4 weeks for anteromedialization, 6 weeks for distalization). They should have their knee brace locked in full extension while walking but can remove it while sleeping. A continuous passive motion machine is used starting the first day postoperatively between 0° and 30° and is advanced as tolerated. Their goal should be to reach 0° to 90° by week 2 postprocedure.

Fig 6. A left cadaver knee in the supine position. A guidewire is shown being placed at the sulcus between the medial epicondyle and the adductor tubercle. A tunnel will be drilled for the gracilis allograft to be placed through for the purpose of medial patellofemoral ligament reconstruction.



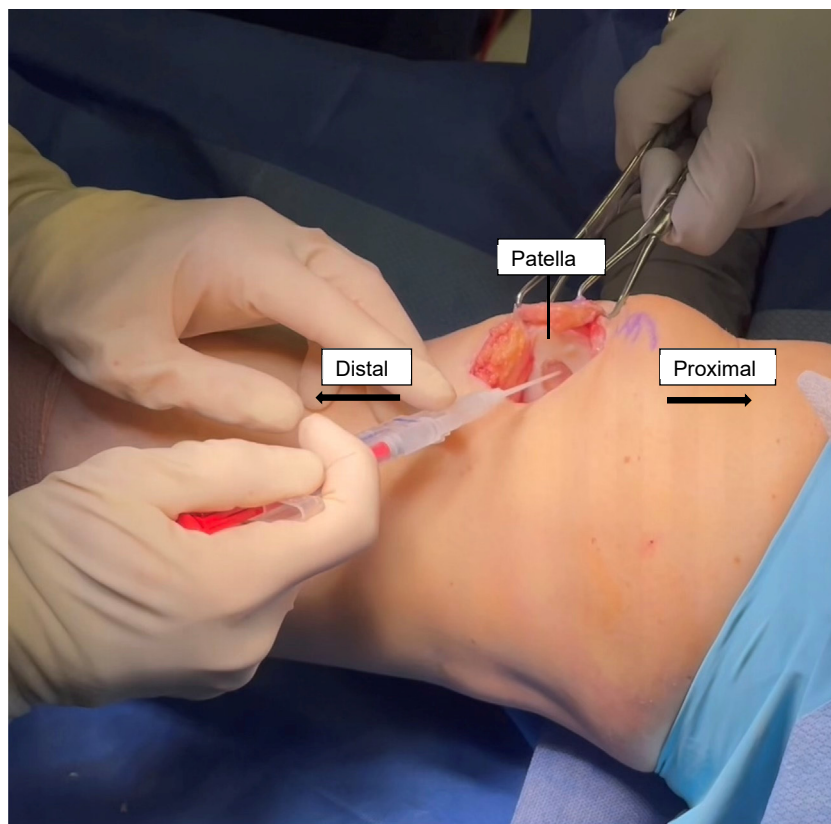


Fig 7. A patient's left leg in the supine position. The everted patella is shown through a lateral arthrotomy. Tisseel (Baxter International) is shown being placed in the defect. The matrix-induced autologous chondrocyte implantation graft will then be placed in the defect and held there for 3 minutes.

In weeks 7 to 12, the patient is weightbearing as tolerated and can discontinue the use of crutches with the guidance of their physical therapist. The brace is used outdoors until the patient feels confident. The patient should have full range of motion at this point.

During weeks 13 to 24, points of emphasis are on regaining strength. If the patient has discomfort over the TTO screws, removal of hardware is encouraged any time 6 months after the index procedure.

Discussion

There is a lack of consensus regarding the treatment of focal chondral defects of the patella. A systematic review by Andrade et al.¹⁷ of 42 studies, including 1,311 knees, showed that MACI, osteochondral autograft transfer system, osteochondral allograft, and particulated juvenile articular cartilage procedures have improved postoperative outcomes. There is variability across studies for which of these techniques is superior, which makes determining a gold standard challenging. The surgeon's choice of repair should depend on their preference and the patient's goals, demographics, activity level, and lesion characteristics.

MACI's increasing use in practice is accompanied by the emergence of various techniques of graft implantation. Fixation of the membrane includes using fibrin glue alone, glue and sutures, or no fixation at all. A

systematic review including 26 studies and 1,539 MACI procedures showed that the implants with no fixation had significantly higher clinical outcomes and lower revision rates.¹⁸ Concomitant realignment procedures of the patella are an essential consideration when treating patellofemoral cartilage pathology. Evidence has shown significantly lower success rates for treating patellofemoral lesions compared with femoral condyle lesions due to the patella's anatomic and biomechanical properties.^{19,20}

Prior studies have demonstrated superior short- and long-term outcomes in patients who underwent autologous chondrocyte implantation (ACI) with concomitant anteromedialization of the tibial tubercle than in patients who underwent ACI alone.²⁰⁻²⁴ Trinh et al.²⁰ have also proposed that performing concomitant distal realignment in patients with chondral lesion(s) on either the patella or trochlea without prior malalignment may be beneficial in protecting ACI that would otherwise be susceptible to mechanical overload.

MACI is the third generation and currently preferred method of ACI, differing from its predecessors in terms of fixation, structure, and, most important, reduced cell leakage and patch hypertrophy.²⁵ Cartilage restoration with MACI has demonstrated excellent outcomes in patients with symptomatic, full-thickness cartilage defects of the knee.

Table 1. Advantages and Disadvantages of Patellar MACI With Concomitant Patellar Stabilization and Realignment

Advantages	Disadvantages
Unloading the cartilage repair site decreases wear on growing cartilage	Slow return to high-impact sports
Stabilizing the patella to prevent further instability avoids cartilage reinjury	MACI graft takes time to grow and mature
Patellar MACI is technically easier than an osteochondral allograft	Uncontained defects are suboptimal for this graft site
Approved by most insurance companies	

MACI, matrix-induced autologous chondrocyte implantation.

Table 2. Pearls and Pitfalls of Patellar MACI With Concomitant Patellar Stabilization and Realignment

Pearls	Pitfalls
Approach the patella from a lateral lengthening/lateral parapatellar approach	MACI graft can be dislodged with ROM, so check it afterward
Use 2 small incisions rather than 1 large one	Knee stiffness may result if patient does not start ROM immediately
Start by preparing the cartilage defect and then go to the osteotomy to improve visualization	
Place screw fixation for osteotomy after the cartilage procedure is finished	

MACI, matrix-induced autologous chondrocyte implantation; ROM, range of motion.

While the aforementioned studies demonstrate that concomitant ACI and TTO have good outcomes, few compare concomitant MACI and TTO to MACI specifically. Results from Gigante et al.²⁶ support the combination of MACI and transfer of the tibial tuberosity, with significant improvement on all outcome scales in their small subgroup of patients.

For patients with patellar instability, a combined MPFL reconstruction with patellar cartilage repair is indicated. While comparative studies investigating combined ACI and MPFL reconstruction are lacking in the literature, Siebold et al.²⁷ showed that this combined procedure had an improvement in patient-reported outcome measures in a cohort of 10 patients, but these findings were not significant. Of note, there were no subsequent dislocations in this patient population. We believe that preventing subsequent dislocation with MPFL reconstruction is crucial to the longevity of the patellar cartilage graft.

We believe that correction of patellar malalignment and instability is crucial to the success of cartilage repair procedures. Therefore, we recommend that concomitant TTO and MPFL reconstruction be performed with MACI procedures of the patella when the anatomic pathology and pertinent patient history described above are present. Tables 1 and 2 illustrate the advantages and disadvantages as well as the pearls and pitfalls of this cartilage repair technique.

Disclosures

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: A.G. is a consultant or advisor for Vericel, Smith & Nephew, and Bioventus LLC; receives speaking and lecture fees from Vericel, Linvatec, Pacira Pharmaceuticals, and Organogenesis;

and has equity or stocks with Smith & Nephew. S.S. is consultant or advisor for Smith & Nephew, Vericel, and Miach Orthopedics; receives speaking and lecture fees from Smith & Nephew, Vericel, and Miach Orthopedics; has equity and stocks with Smith & Nephew; and has received travel reimbursement from Smith & Nephew. All other authors (C.F., M.R.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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