Technical Note

LIPO-AMIC Technique Description: Autologous Matrix Induced—Chondrogenesis With Microfragmented Adipose Tissue Graft

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Abstract: Cartilage injuries have historically been challenging to manage, but recent advancements have rapidly expanded treatment options. The incorporation of mesenchymal stem cell sources, such as bone marrow or adipose tissue, has improved repair tissue quality and clinical outcomes. The LIPO-AMIC procedure for full-thickness knee cartilage lesions uses a collagen matrix combined with microfragmented adipose tissue grafts as a source of adipose-derived stem cells, leveraging their chondrogenic differentiation capacity and paracrine activity. This adaptation aims to enhance outcomes and provides a single-stage knee cartilage repair option with biological augmentation.

Cartilage injuries have long been recognized as challenging, even deemed untreatable, as published by William Hunter in 1743.[1] Fortunately, this topic has gathered increasing interest in recent decades, resulting in an expansion of treatment options.[2-4] In the context of focal lesions, exclusive arthroscopic repair options with proven safety and efficacy, such as shaver-minced cartilage and osteochondral allograft transplantation, are also being explored.[5,6] Benthien and Behrens[7] introduced the autologous matrix-induced chondrogenesis (AMIC) technique, which implants a type I and III collagen matrix (Chondro-Gide; Geistlich Pharma AG) to cover the area of the chondral defect treated by microfracture and stabilize the bone marrow clot "superclot" during organization while permitting the mesenchymal stem cells (MSCs) to develop into chondrocytes.

Other more robust sources of MSCs were subsequently described, notwithstanding. In this context, bone marrow or adipose tissue and adipose-derived stem cells (AD-MSCs) may produce progeny belonging to several differentiation lineages, but their therapeutic potential is mostly based on their immunomodulatory functions and paracrine regulatory activity in situ.[8] AD-MSCs provide a safe and promising option for enhancing cartilage repair. The addition of the microfragmented stromal vascular fraction (SVF) to microfractures provided statistically better clinical results compared to microfractures alone.[9]

In this article, we present the technique for focal, full-thickness knee cartilage lesion repair with the LIPO-AMIC procedure, an autologous matrix—induced chondrogenesis associated with microfragmented adipose tissue graft.

Surgical Technique

Evaluation and Planning

A comprehensive clinical assessment of the patient is essential for the successful treatment of knee chondral lesions. Supplementary evaluation in cases of suspected symptomatic chondral lesion should include panoramic radiography of the lower limbs, orthogonal weight-bearing radiographs, and magnetic resonance imaging

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(MRI) of the knee. Correction of coronal plane alignment should be considered for malalignments greater than 2° to 3° with overload of the affected compartment.[10] The patient alignment evaluation is presented in Figure 1.

Preparation of Microfragmented Adipose Tissue Graft

The patient lies supine on a radiolucent surgical table under anesthesia, with available free limb mobilization and an optional tight support and tourniquet at the upper tight. Prepare the surgical site and drape the limb to be operated on, as well as the site for fat aspirate collection (abdomen, flanks, inner thigh). For abdomen collection, 180 mL of tumescent (Klein's solution) is infiltrated into each flank through a small incision just sufficient for the introduction of the cannulas. Local anesthesia should be administered at the incision sites before or after the procedure, according to the anesthetic plan. Klein's solution is composed of 1 L of normal saline (0.9% NaCl) + 100 mL of 1% lidocaine (10 mg/mL = 1,000 mg) + 1 mL (1 ampule) of 1:1,000

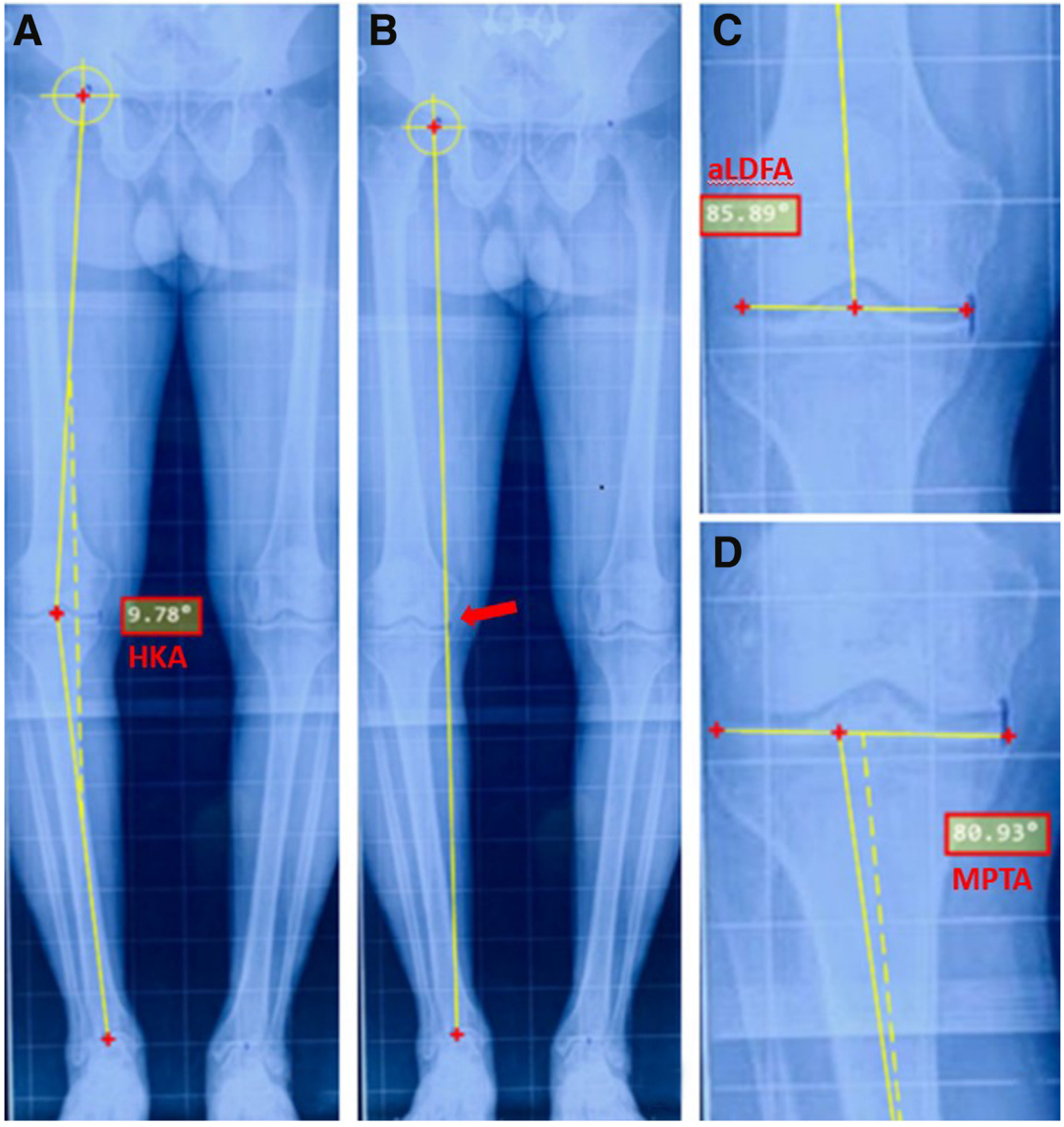

Fig 1. Representative case involves a 45-year-old male patient. The alignment correction planning using panoramic radiography of the lower limbs reveals a varus alignment of 9.78° in the right knee (A), with the mechanical axis intersecting the medial compartment at 5.7% of the width of the tibial plateau (arrow) (B). The anatomic lateral distal femoral angle (aLDFA) was is 85.89° (C), and the medial proximal tibial angle (MPTA) is 80.93° (D). The center of rotation of angulation is contained within the bone, at 14.92% of the tibial length from the proximal articular surface, characterizing an abnormal varus alignment of the right lower limb primarily due to a metaphyseal varus deformity of the proximal tibia, along with a minor varus deformity of the distal femur. (HKA, hip-knee-ankle angle.)

epinephrine (1 mg/mL = 1 mg). The addition of 10 mL of 8.4% sodium bicarbonate (10 mEq) is optional; we do not use it routinely. After 15 minutes, 60 mL of aspirated fat is extracted using a blunt 13-gauge cannula. The lipoaspirate is processed using the commercially available Lipogems kit (Lipogems International SpA), and 3 cycles of microfragmentation, followed by irrigation with saline solution, are performed on the accessory surgical table (Fig 2, Video 1). The resulting adipose graft exhibits high viscosity, allowing for manipulation with delicate surgical instruments. Approximately 7 to 10 mL of the final product is required for the described LIPO-AMIC technique.

Cartilage Repair

Arthroscopic inspection, treatment of concomitant lesions, or cartilage site preparation can be performed while Klein's solution is in effect, as well as while the fat aspirate is being processed, depending on the availability of the surgical team throughout the procedure. Limb axis realignment and treatment of concomitant lesions should ideally be performed using the same procedure. Varus deformity may be corrected (Fig 3). For the repair of the chondral lesion, exposure is achieved through a medial parapatellar mini-arthrotomy, the edge of the lesion is addressed using a scalpel blade, delicate straight periosteal elevator, and curettes, aiming for perpendicular edges of healthy cartilage, which will serve as containment for the previously prepared microfragmented adipose tissue graft and anchorage for the membrane (Fig 4). The calcified cartilage layer should be completely and gently removed from the lesion bed, without violating the subchondral bone[11]; tactile and auditory cues may be useful during the use of curettes. Punctate bleeding demonstrates an adequate depth of debridement.[12]

Subsequently, a mold of the lesion is made using the laminated sheet from the Chondro-Gide kit (Geistlich Pharma AG), aiming for a perfect match while avoiding overlaps and coverage gaps. Next, the smooth surface of the implantable membrane is marked with a Codman pen ("Up"), facilitating the identification of the side that will face the joint the rough surface will receive the adipose graft and will face the lesion bed. The membrane is then cut in reference to the produced mold, aiming for a slightly smaller final area, as the membrane will expand by 10% to 15% after soaking in saline. The correct fit should be tested, aiming for a perfect match. Any edges that may exceed the border should be excised for a perfect fit, taking care to avoid excessive tension after suturing. Excessive tension can occur if the membrane is excessively reduced or if there are elongated lesions of the condyles due to the effect of femoral curvature.[10] This can reduce the available space for the microfragmented adipose tissue graft, limit the maturation of repair tissue in the central portion, and weaken suture fixation.

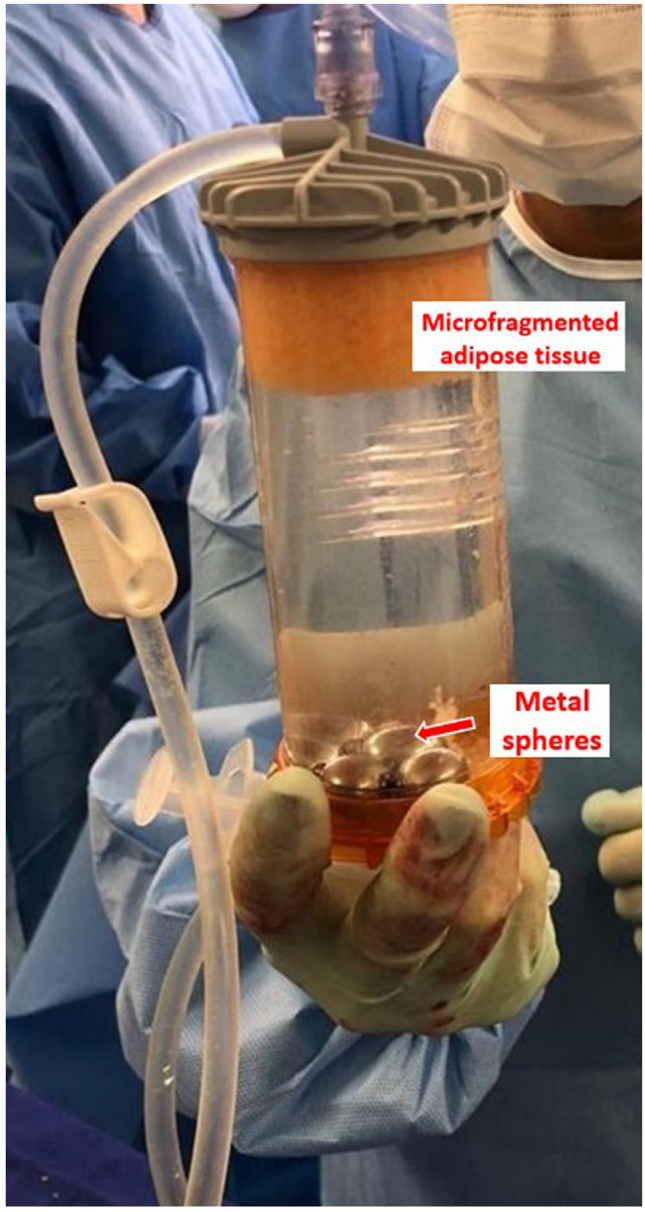

Fig 2. Accessory surgical table view. The lipoaspirate is processed using the commercially available Lipogems kit (Lipogems; Lipogems International). Three cycles of microfragmentation are performed. The device is shaken, as the mobile metal spheres mechanically act on the fat aspirate, resulting in the appearance shown, with the microfragmented adipose-tissue graft resting in the upper third of the device, to be subsequently collected through the upper filter.

After moistening the membrane, it is positioned in a liquid-free basin with the "Up" marking facing downward, and 2 mL of microfragmented adipose tissue graft is applied to the rough surface that will come into contact with the lesion, with the help of a syringe and delicate spatulas. The membrane is then allowed to rest

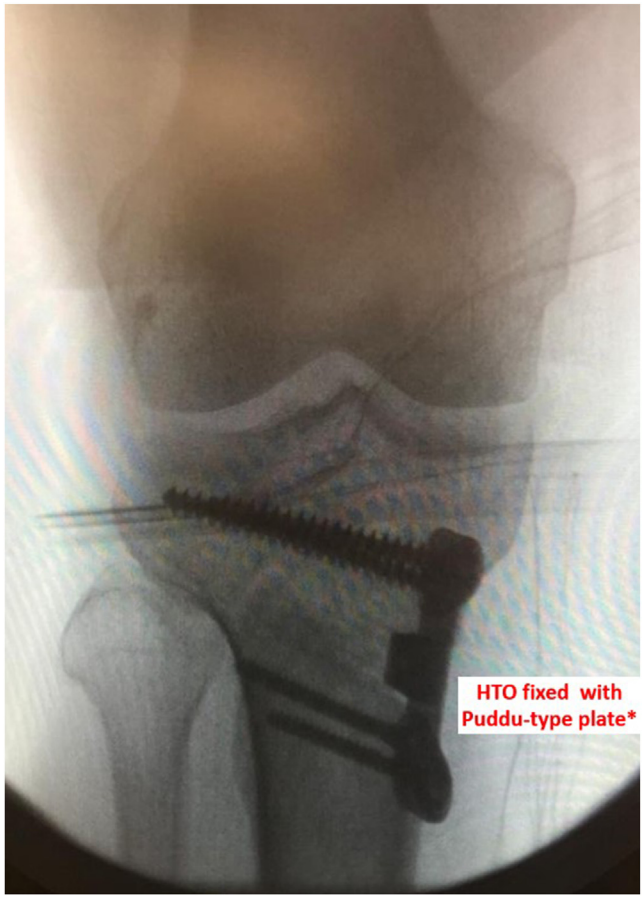

Fig 3. Right knee intraoperative fluoroscopy anteroposterior view. A high tibial osteotomy (HTO) was performed using a medial wedge technique. A 10-mm opening was achieved using a temporary metallic wedge introduced in the most posterior part of the osteotomy site, following a preoperative plan to achieve neutral alignment. (*) Fixation was performed with a Puddu-type Tibial A/P Sloped Osteotomy Plate (Arthrex). The osteotomy gap was filled with a structured autologous iliac crest graft.

for 5 minutes to ensure thorough absorption of the graft material. The characteristic high viscosity ensures graft adherence to the rough surface of the membrane (Fig 5, Video 1). The chondral defect is further filled with microfragmented adipose tissue graft, and then the membrane is carefully applied over the lesion to ensure that the graft is contained and adequately fills the defect, avoiding overflow, overfilling of the cavity, or excessive tension on the membrane.

Fixation is performed using interrupted absorbable sutures with 6-0 PDS (Ethicon) anchored at the edge of the cartilage with a spacing of 3 to 5 mm (Fig 6). The knot should be tied and placed on the inner surface of the lesion, over the membrane, to remain below the level of adjacent cartilage and provide sufficient sealing. Additional fixation is performed externally with fibrin glue to prevent graft leakage. The knee is flexed from 0° to 90° through 5 cycles to assess the stability of the repair, concluding the surgical procedure of the LIPO-AMIC chondral repair technique.

Postoperative Protocol

Rehabilitation begins immediately after surgery, focusing on quadriceps activation and strengthening measures. During the first 10 days, the patient should flex the knee up to a maximum of 30° and then gradually increase knee flexion as tolerated. The use of a continuous passive motion (CPM) device is recommended, and the patient is instructed to perform exercises regularly at home.

For the first 4 weeks, the patient should maintain toe-touch weightbearing with crutches, between weeks 4 and 6, and then progress to partial weightbearing with 50% to 60% of body weight. By the end of week 6, the patient is encouraged to apply full weightbearing on the operated limb. Rehabilitation continues with the training of work/sporting gestures initiated after 8 weeks.

Discussion

This study aims to introduce an adaptation of the LIPO-AMIC surgical technique for single-stage repair of full-thickness knee lesions. The procedure incorporates the use of the Chondro-Gide membrane (Chondro-Gide; Geistlich Pharma AG) and microfragmented adipose graft processed using Lipogems (Lipogems International SpA), with adjustments made to the technique described in existing literature. The objective is to establish a standardized surgical and postoperative protocol for use in future prospective studies aimed at evaluating clinical and radiologic outcomes.

A recent systematic review and meta-analysis conducted by Steinwachs et al.[13] evaluated the safety and medium- to long-term outcomes of AMIC repair. The analysis confirmed long-term clinically persistent improvement in the treatment of grade III to IV cartilage lesions with AMIC. In a comparative systematic review between AMIC and matrix-induced autologous chondrocyte implantation (mACI) conducted by Migliorini et al.,[14] significantly better results and a lower rate of complications were identified in the AMIC group.

Exploring the rationale of chondrogenic differentiation capacity and paracrine activity of AD-MSCs, in addition to the ease of obtaining a large number of cells through processing of the lipoaspirate, microfragmented adipose graft emerges as a viable option.[9,15] Siennicka et al.[8] assessed the safety of using MSCs from the adipose tissue with no serious adverse events reported. Improved patient-reported outcome measures (PROMs) and radiologic outcomes were observed with the combination of microfracture and AD-MSCs compared to isolated microfracture on focal or diffuse/osteoarthritic lesions.[16,17] Kyriakidis et al.[18] tested

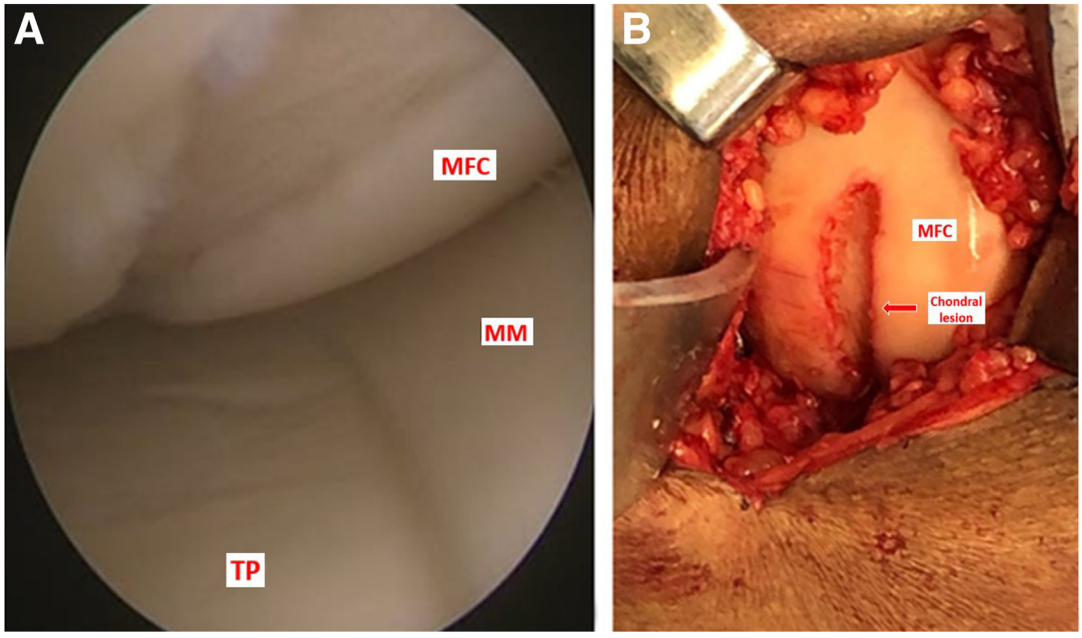

Fig 4. (A) Arthroscopic view of the right knee medial femoral condyle (MFC), medial meniscus (MM), and tibial plateau (TP) trough lateral portal. (B) MFC view through a medial parapatellar mini-arthrotomy and knee flexion, showing the chondral lesion aspect after edge preparation and curettage of the lesion bed (without microfracture).

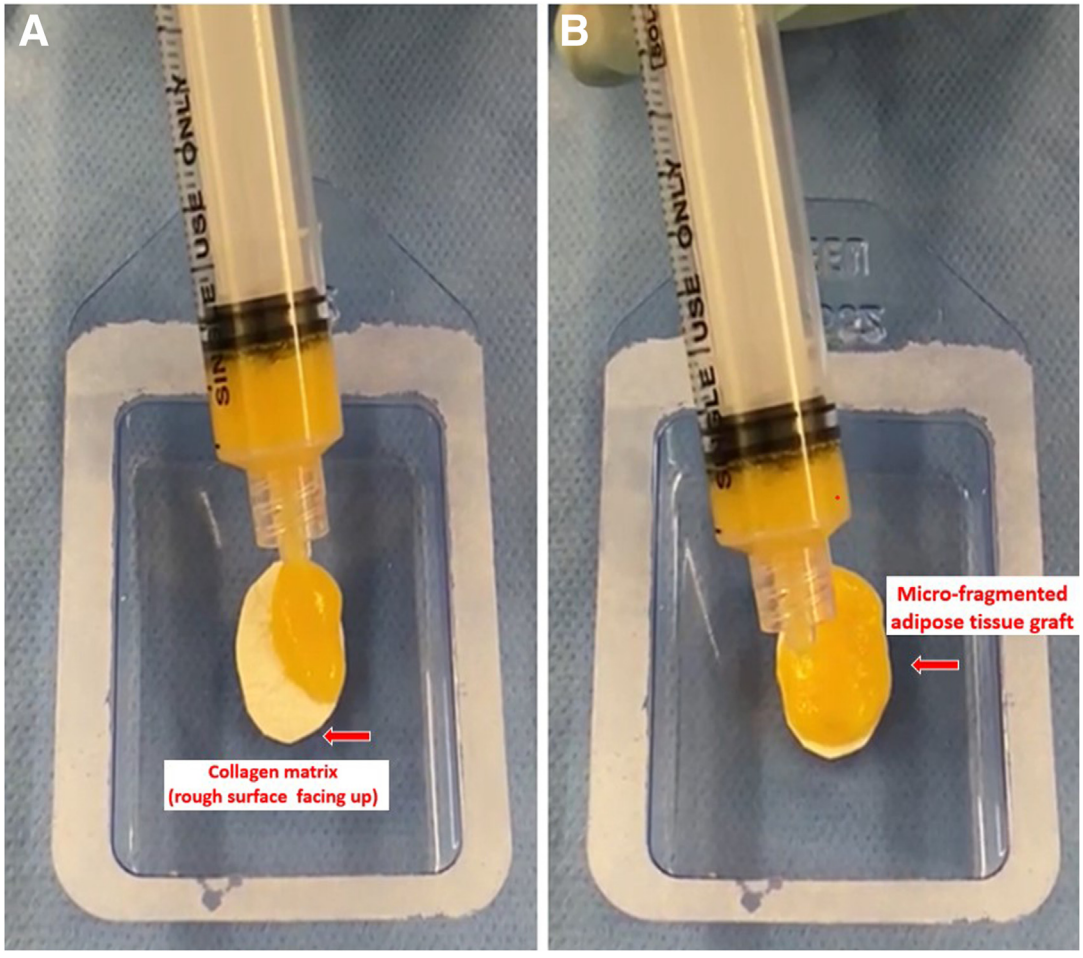

Fig 5. Accessory surgical table presenting LIPO-AMIC membrane aspect before implantation. The microfragmented adipose tissue graft is carefully applied to the rough Chondro-Gide matrix surface with a syringe and adjusted with delicate spatulas, demonstrating satisfactory adhesion.

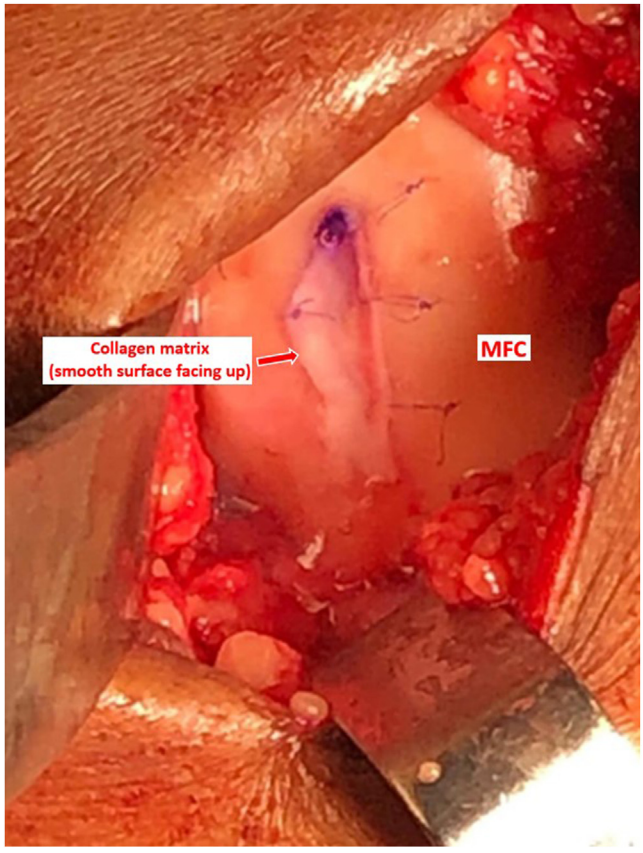

Fig 6. Medial parapatellar mini-arthrotomy with knee flexion to approach right knee medial femoral condyle (MFC). Final repair with LIPO-AMIC. Defect filled with microfragmented adipose tissue, scaffold adjusted, and sutured with 6-0 PDS sutures (Ethicon). Care must be taken to avoid excessive suture tension.

culture-expanded adipose-derived MSCs embedded in a trimmed-to-fit biodegradable matrix, demonstrating an effective and safe procedure.

Meanwhile, Sciarretta et al.[19] presented in 2017 their repair technique of focal lesions with AMIC associated with a microfragmented adipose tissue graft processed with Lipogems, applied through membrane soaking, defined as LIPO-AMIC. All 18 patients were followed up for 5 years, and there were no complications, indicating the safety of the procedure. They presented promising results with statistically significant and persistent outcomes for the treatment of full-thickness cartilage defects. All patients showed significant improvement in scores at the 6-month to 5-year follow-ups. The magnetic resonance observation of cartilage repair tissue score increased from 69.1 to 81.9 in the second through fifth years, and complete defect filling was observed in 77.8% of cases.[20]

We propose an adjustment to the LIPO-AMIC technique, with direct grafting of microfragmented adipose tissue into the chondral defect, filling the entire lesion to provide a greater number of AD-MSCs. The proper application of the Chondro-Gide membrane ensures containment of the graft, and the formed superclot promotes a favorable microenvironment and serves as a scaffold for differentiation and maturation. The procedure mini-open parapatellar arthrotomy ensures proper defect preparation, filling, and fixation. Additional pearls and pitfalls are presented in Table 1.

Strategies for focal chondral repair involving the combination of orthobiologics and scaffolds demonstrate satisfactory clinical outcomes and exhibit a favorable safety profile.[2,13,21,22] The LIPO-AMIC emerges as a reliable option, with promising initial clinical results, and it is safe and feasible to perform in a 1-step procedure. However, further clinical studies are needed to assess the reproducibility of the previously published outcomes and investigate the impact of the proposed modifications.

Disclosures

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: P.D. is a consultant or advisor for Arthrex and Geistlich Pharma AG. K.L.W. is a consultant or advisor for Geistlich Pharma AG. M.C. is a consultant or advisor for Arthrex. C.C.K. is a

Table 1. Pearls and Pitfalls of the LIPO-AMIC Technique: Autologous Matrix-Induced Chondrogenesis With Microfragmented Adipose Tissue Graft

Pearls	Pitfalls
Harvest the adipose tissue graft from the region where there is the greatest accumulation of fat—if it is from the lower limb, harvest symmetrically bilaterally.	Athletes and very thin patients may present a challenge in collecting adipose tissue. Uncontained chondral defects are challenging and often require limited debridement to preserve the best edge.
To access a cartilage lesion, perform a parapatellar approach, medial if the lesion is in the medial condyle or in the patella and lateral if the lesion is in the lateral condyle. Wide exposure contributes to the adhesion of the membrane. For more posterior injuries, increased knee flexion is necessary during access.	During the suturing of the membrane, there may be extravasation of adipose tissue—reserve 5 mL of adipose tissue in case it is necessary to infiltrate it submembranely after completing the suture and before administering the glue.
Mold the membrane with enough slack when lesions are in convex areas to prevent constriction of the central space available for grafting.	

consultant or advisor for Arthrex and Geistlich Pharma AG. The author G.G.R. declares that he has no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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