Acellular Matrix-Induced Chondrogenesis Technique Improves the Results of Chondral Lesions Associated with Femoroacetabular Impingement

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Purpose: The study's main objective was to evaluate, in the short-term, the result of the autologous acellular matrix-induced chondrogenesis (AMIC) technique in a selected group of patients with 2-4 cm^2 full-thickness chondral lesions, undergoing hip arthroscopy for femoroacetabular impingement (FAI). **Methods:** A retrospective single-center Level IV case series of 25 patients (28 hips) who underwent an arthroscopic hip surgery with a liquid acellular collagen matrix. Inclusion criteria for implantation were FAI diagnosis (cam or pincer type), grade IV chondral lesions (Outerbridge size 2-4 cm^2); Tönnis stage 0-II, minimum follow-up of 24 months, and 1 year (12-15 months) evaluation with very high field 3-T MRI arthrography. Exclusion criteria were Tönnis III, joint space <2 mm, center-edge angle <20°, and <24 months of follow-up. Clinical assessments involved symptoms duration until surgery, changes in physical and work activity and range of motion, modified Harris Hip Score, reporting percentages of patient acceptable symptomatic state (PASS) and minimal clinically important difference (MCID), pain with a VAS, and level of satisfaction. Radiological assessments: Tönnis stage, articular space, alpha and lateral center edge angle (Wiberg), and generated tissue characteristics at 1 year (based on the MOCART score), through 3-T MRI. **Results:** 25 patients (28 hips) treated; 19 men and 6 women (mean age: 40.5 years; range: 25-55). Two women underwent joint replacement surgery. Thus, 23 patients (26 hips) were analyzed. At 29 months following surgery (range: 24-48), a significant improvement was obtained in all parameters assessed, focusing on the characteristics of the generated tissue in the MRI (MOCART scores). 95% of the patients met the MCID (improvement >12 points in the modified Harris Hip Score), and 100% scored >74 points, achieving the PASS. Patients' satisfaction was 86.6% (SD 16.4). All patients who practiced sports resumed them. **Conclusions:** The liquid AMIC is a safe technique that shows good clinical and radiological outcomes in a 2-year follow-up in patients with femoroacetabular impingement and grade IV acetabular 2-4 cm^2 chondral defects. **Level of Evidence:** Level IV, retrospective case series.

Introduction

Diagnosis and treatment of chondral lesions continue to represent a challenge for orthopedic surgeons and basic science researchers.[1] The limited regeneration capacity of these lesions and their occurrence in young and active patients make them a focus of interest and research on different techniques that will allow creating a tissue that can imitate, in a lasting manner, the characteristics of the hyaline cartilage.[2,3]

Increased knowledge developed concerning femoroacetabular impingement (FAI), treatment of the labrum, capsular management, and osteoplasty are important reasons for increased hip arthroscopy procedures in hospitals.[3]

The bone deformity associated with femoroacetabular impingement (FAI), mainly the cam deformity, results in chondro-labral junction stress and a common cause of primary degeneration of the labrum and the adjacent cartilage, which predisposes one to premature osteoarthritis, as the cartilage gradually degenerates if left untreated.[4–9]

Acetabular chondral damage could be present in 20 to 40% of patients undergoing hip arthroscopy, and in

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these cases, when compared with no chondral lesion groups, worse functional outcomes, lower satisfaction rates, and greater pain have been reported, in direct relation to the degree of chondral damage.[10,11]

The arthroscopic surgical techniques available for the treatment of chondral lesions include the different subchondral bone stimulation techniques (e.g., microfracture), direct chondral suture, the use of fibrin patches, the implantation of autologous chondrocytes, with or without a membrane (autologous chondrocyte implantation [ACI], matrix-applied chondrocyte implantation [MACI]), and autologous acellular matrix-induced chondrogenesis techniques (AMIC),[12] which is our choice. This AMIC technique provides an acellular collagen type I/III matrix that acts as a scaffold, supporting cell adhesion, growth, and differentiation.[13] Collagen matrices have previously been shown to support chondrogenic differentiation of mesenchymal stem cells from subchondral bone,[14] and to maintain chondrocyte phenotype.[15,16]

However, there is still limited knowledge on the médium-long term results of these types of hip arthroscopy treatments. Regarding these techniques, the available literature mainly engages in a clinical assessment of patients, with very few studies focusing on an objective assessment using imaging techniques, such as magnetic resonance imaging (MRI).[17] The MRI has proven to be a valuable tool to evaluate the acetabular cartilage condition.[18] Moreover, there are few cases in which a second arthroscopy procedure can be performed to assess the repaired area, and there are ethical concerns with collecting a biopsy sample.[19]

The study's main objective was to evaluate, in the short term, the result of the acellular collagen type I matrix implantation (AMIC) technique in a selected group of patients with 2-4 cm^2, full-thickness chondral lesions, undergoing hip arthroscopy for FAI. We hypothesized that proper treatment of grade IV chondral lesions with an acellular collagen matrix demonstrated by a 3T MRI control of the generated tissue would show favorable clinical and functional results.

Methods

Study Design

A retrospective single-center level IV case series was conducted on the basis of prospectively collected data of 25 patients (28 hips)—treated with a liquid acellular type I collagen implant (AMIC) because of a grade IV acetabular chondral lesion, size 3 cm^2 (range 2-4 cm^2)—who underwent hip arthroscopy with FAI diagnosis. This acellular collagen implant was first used at our hospital in October 2016 and is our method of choice for all IV Outerbridge acetabular defects >2 cm^2. At the time of this study was performed (Jun 2020), 44 patients (47 hips) had undergone this procedure in our hospital.

The study was approved by the Drug Research Ethics Committee (*Comité de Ética de Investigación con Medicamentos*, CEIm). All the patients signed informed consent for the collection of data and the publication of this article.

Subjects

The study enrolled men and women aged 18-55 years old with grade IV acetabular 2-4 cm^2 chondral lesions. Inclusion criteria were 1) FAI diagnosis (cam or pincer type); 2) grade IV acetabular 2-4 cm^2 chondral lesions, based on the Outerbridge classification; 3) Tönnis stage 0-II; 4) minimum follow-up of 24 months, and 5) 3-T MRI postsurgical control, performed with a traction system that allows separating both sides of the joint for better analysis of the acetabular surface, 1 year following surgery (12 to 15 months). Exclusion criteria were 1) value on the Tönnis classification system $\geq$ III; 2) articular space <2 mm; 3) coverage defect with a center-edge (CE) angle <20°; and 4) follow-up shorter than 24 months or absence of control MRI at the time of data analysis.

For image assessment, a pelvis anteroposterior R-ray was performed on the basis of Siebenrock's quality criteria,[20] and an axial X-ray based on Dunn at 45° degrees flexion.[21]

Surgical Technique

All of the patients enrolled in the study underwent the same surgical technique by the same surgeon, hip arthroscopy was performed, and implantation of a liquid acellular collagen matrix ChondroFiller (Meidrix Biomedicals, Esslingen, Germany), which provided a type I collagen matrix to fill and adapt to the existing defect. It consists of a double chamber syringe designed for the application during arthroscopy of liquid collagen type I; used for defect sizes 2-4 cm^2, which 5-7 minutes after injection, forms a dimensionally stable gel that, because of its adhesiveness, does not require the use of fibrin glue, even when it is used against gravity.

With the patient in the supine position, with a traction table, and under fluoroscopic guidance, the hip's central compartment is accessed through the anterior trochanteric portal to identify lesions in the central compartment.[22] When a chondral lesion is present, curettage is performed until reaching the stable rims of the cartilage perpendicular to the lesion.[22] Acetabular reaming is routinely performed to decrease the area's surface exposed with grade IV lesion and prepare for labral reattachment with PushLock knotless type implants (Arthrex, Naples, FL), with special care to avoid excessive bone resection. The chondral lesion's surface and location are determined with a calibrated palpator,[23,24] (Fig 1), and then, the traction is removed to resect the cam-type deformity in the peripheral compartment.[25] T-capsulotomy is regularly performed.

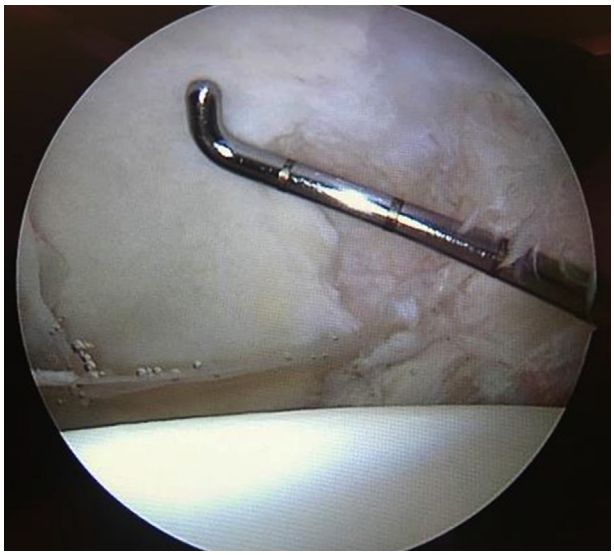

Fig 1. Anterior trochanter portal detail of the right hip chondral defect with a calibrated palpator.

A vertical capsulotomy is repaired in all males, and total closure is repaired in all females.[26]

Upon completion and confirmation of the resection under fluoroscopic guidance, the central compartment is again accessed under traction. A suction cannula is introduced using a posterior trochanteric accessory portal, which allowed us to dry the joint, as the liquid acellular matrix must be applied in dry conditions. The acellular type I collagen matrix was previously thawed from 5 to 10 minutes before the implantation. At 5-7 minutes following the injection, a dimensionally stable gel is formed. Ten minutes following application, the matrix is completely stabilized, traction can be released, horizontal capsular closure is performed in female patients, and the procedure is completed. (Table 1, Fig 2)

Postsurgical Rehabilitation Protocol

Following the procedure, patients kept the operated leg in full rest, at 5° to 10° of flexion for the first 24 hours, allowing non-weight-bearing ambulation for 3 weeks, partial weight-bearing (20-30 kg) from week 4 to week 6, and full-weight bearing as of week 7 to week 8.

At 9-10 days following surgery, progressive movement and soft stationary bicycle exercise were initiated. During the first month, neither flexion of the upper hip higher than 90° nor rotations were allowed. After six weeks, progressive strengthening and mobilization exercises with no limit to the mobility arch were performed.

In this particular group of patients with large 2-4 cm^2 chondral defects and AMIC procedure, no-impact exercise is allowed the first post-op year, to protect the biological maturation produced in the matrix.[27]

Clinical and Radiological Variables Assessed

All patients were clinically and radiologically assessed before the procedure at 6 weeks following surgery, at 3 months, 6 months, and a year following the procedure, and subsequently, with an annual follow-up. To evaluate the characteristics of the generated tissue with the AMIC technique, a very high field 3T resonance arthrography was used, with specific hybrid morphological sequences for assessing the cartilage.[28] For optimal analysis, it is essential to achieve a good separation on joint surfaces by manual traction and leg rotations, with the application of a traction system with weights later, which improves the image's resolution and the reliability and detection of chondral lesions.[18]

Patients were examined at the physician's office before the surgery to confirm the diagnosis of femoroacetabular impingement.

Data were collected on the onset of symptoms, work and sport activity, pain recorded on the VAS scale, hip mobility, and the modified Harris hip score (mHHS) was completed reporting the percentage of patients that met the patient acceptable symptomatic state (PASS),[29] and minimal clinically important difference (MCID).[30,31]

Anteroposterior and axial radiograph of the pelvis at 45° of flexion, the Tönnis stage, articular space in millimeters, α angle, and acetabular coverage angle were determined using the Syngo.via Imaging VB30 system (Siemens Healthcare, Erlangen, Germany). (Figs 3 and 4)

Preoperatively and in the event of suspected articular pathology, our site routinely conducts an arthro-MRI to confirm the FAI diagnosis.

At 12-15 months following surgery, imaging control was performed by direct/indirect very high field 3T resonance arthrography technique with specific morphological hybrid sequences for the assessment of the cartilage, with prior manual traction and leg rotations for 2 minutes, inguinal-crural bandage, fixation by traction harness and application of a weight leg traction system (between 9 and 18 kg, based on the patient's BMI) (Fig 5). This procedure ensured an optimum scan, with higher reliability of the integration and the tissue generated by the collagen matrix,[32] allowing the analysis employing the Magnetic Resonance Observation of Cartilage Repair Tissue (MOCART) system.[33] (Table 2)

The MOCART system is used to study the implanted matrix's behavior and represents a well-known tool for

Table 1. Surgical Procedures Performed

Procedure	Number of Hips
Labral repair	28
Labral debridement	0
Acetabuloplasty	28
Femoraplasty	28
Partial capsular repair	19
Total capsular repair	6
AMIC	28

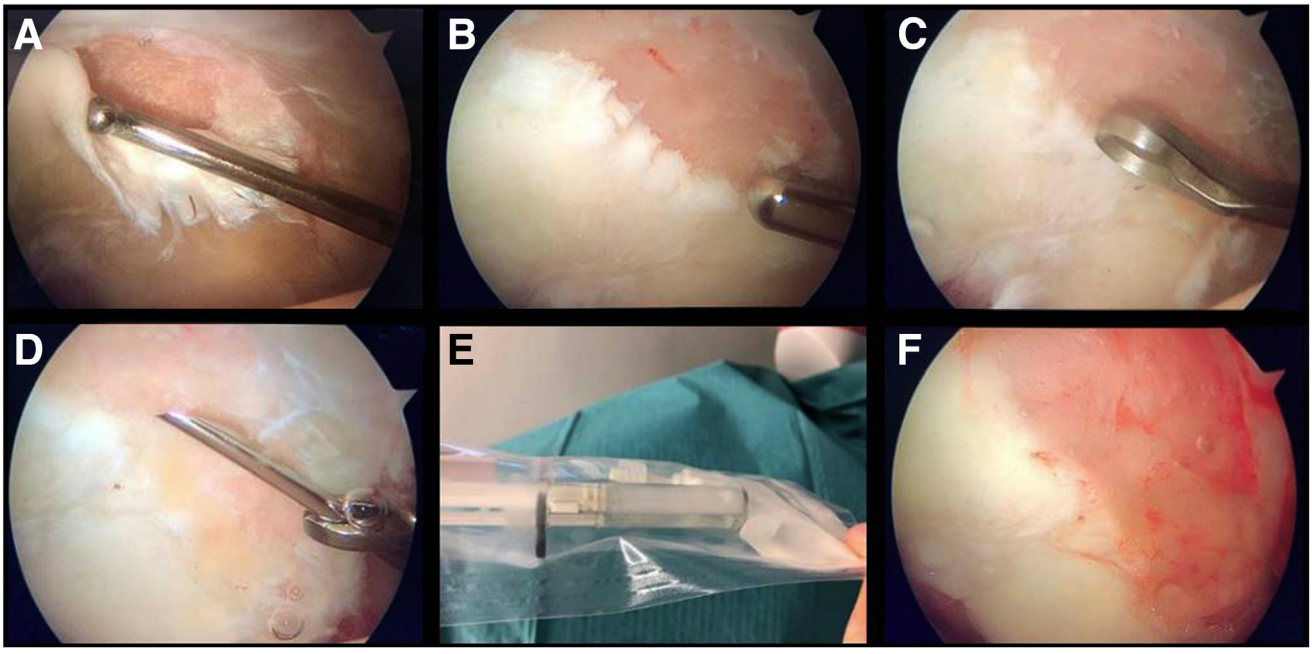

Fig 2. Right hip lesion and procedures applied. (A) Full-thickness lesion. (B) and (C) Resection of loose fragments of cartilage and trimming to a stable rim, with minimal abrasion of the subchondral bed. (D) Acellular matrix insertion planning. (E) Liquid acellular collagen matrix thawing before application. (F) Full defect coverage matrix.

assessing cartilage repair, with good interobserver reproducibility and clinical outcome correlation.[33] Eleven variables were analyzed, providing a quantitative estimate, for instance, of the signal shown by the regeneration tissue, subchondral integration, and the adjacent chondral tissue, presence of subchondral edema, among others[32] (Table 2).

Data Management

The statistical analysis was performed on the basis of results obtained from preoperative values and those of the last follow-up from all of the data obtained throughout the study. The surgeon (J.C.L.V.) diagnosed and followed up the patients, F.T. completed the patient-reported outcome measures, M.S. completed the radiological, and M.M. performed the MOCART evaluation.

Statistical Analysis

For the statistical analysis, the software used was the SPSS11.5 statistical package for Windows. Quantitative variables were described as the mean and standard deviation (SD) and the maximum and minimum range. Qualitative variables were described as absolute

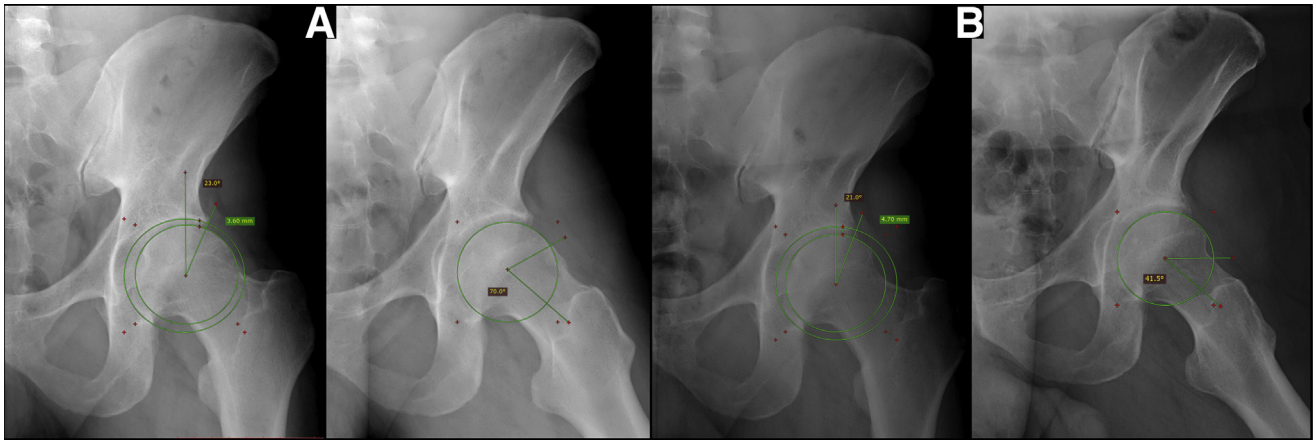

Fig 3. Anteroposterior (AP) and axial right hip radiographs of the presurgical and postsurgical evolution. The articular space maintenance at 37 months postsurgery can be observed, and with no degenerative sign progression: (A) Presurgical AP and axial radiography (α 70°, CE 23° articular space 3.6 mm), (B) Postsurgical radiography at 37 months, AP and axial (α: 41.5°, CE: 21° articular space: 4.7 mm).

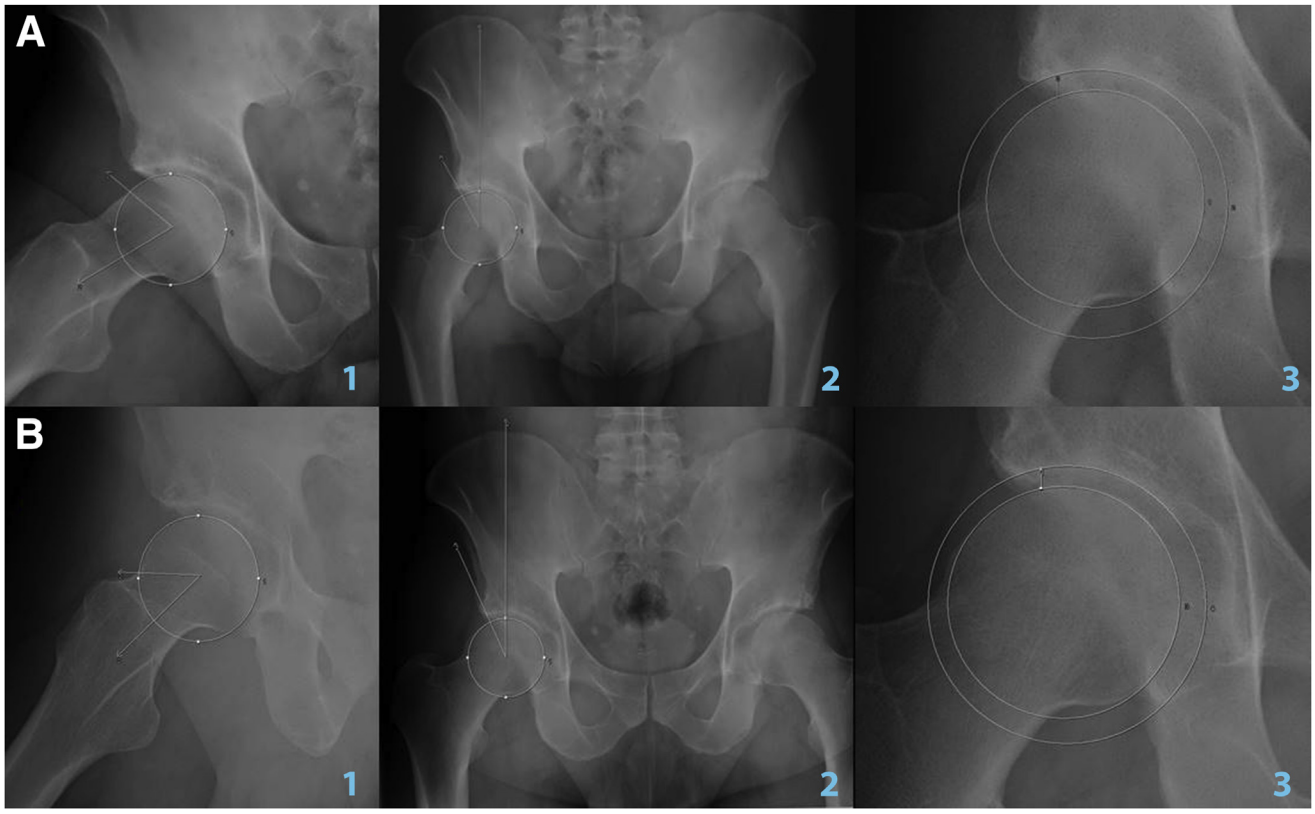

Fig 4. Anteroposterior (AP) and axial right hip radiographs, example of pre and postsurgical radiological measurements. (A) Upper row: (1) presurgery α-angle 70°; (2) center edge (CE) 29° (3) joint distance 50 mm. (B) Lower row: (1) postsurgery at 30 months α 45°; (2) CE 25° (3) joint distance 55 mm.

frequency and or percentage. The efficacy outcomes were assessed as the change of the corresponding variable from the time baseline to the last follow-up. In quantitative variables, the tests used were the Student's *t*-test (parametric analysis); a *P* value of .05 or less was considered statistically significant.

Results

The author (JCLV) has been performing arthroscopic surgery of the hip since 2009 and started using acellular collagen implants in 2016.

With the inclusion criteria described, 25 patients (28 hips) were enrolled, with a mean age of 40.5 years old (SD: 7.1, range: 25-55), of which 19 were male, and 6 were female.

Two women underwent joint replacement surgery within the first year of the procedure and could not complete the study.

Thus, until June 2020, the data from 23 patients (26 hips) are presented, with a mean follow-up of 29 months (range: 24-48). Not one of these patients was lost to follow-up.

The mean time elapsed from onset of symptoms to the surgery date was 29.8 months (SD 9.9; range: 18-48). Most chondral lesions were found between 11 and 15:00 hours, ranging from 3 cm^2 (SD 1), and 14 cases presented 4 cm^2 lesions.

Eighteen patients who practiced sports activities actively and regularly had to stop the activity before the surgery (Table 3). The range of motion from preoperative to the last follow-up is shown in Table 4.

The mean pain score based on the visual analog scale (VAS) before surgery was 7.6 (SD: 2.1, range: 3-10) and, in the last follow-up, 1.4 (SD: 1.2, range: 0-4.5); the difference being statistically significant ($P < .0001$). Eighteen patients (78%) presented no pain (VAS of 0 to 2), and no patient reported severe to very severe pain (6 to 8) or very severe to the worst possible pain (8 to 10).

The mHHS score, from a preoperative mean value of 62.8 (SD 14.3) points improved to a mean value of 95.8 (SD 8.1) in the last follow-up. The difference was statistically significant ($P < .0001$). Twenty-two out of 23 (95%) of the patients met the MCID, as they improved more than 12 points in the MHHS in the last follow-up, and 23 patients (100%) scored more than 74 points, thus achieving the PASS.[31]

Patient satisfaction (0-100%) was performed via the next direct question: What would you say, comparing to the normal preinjury state of the hip joint that is your

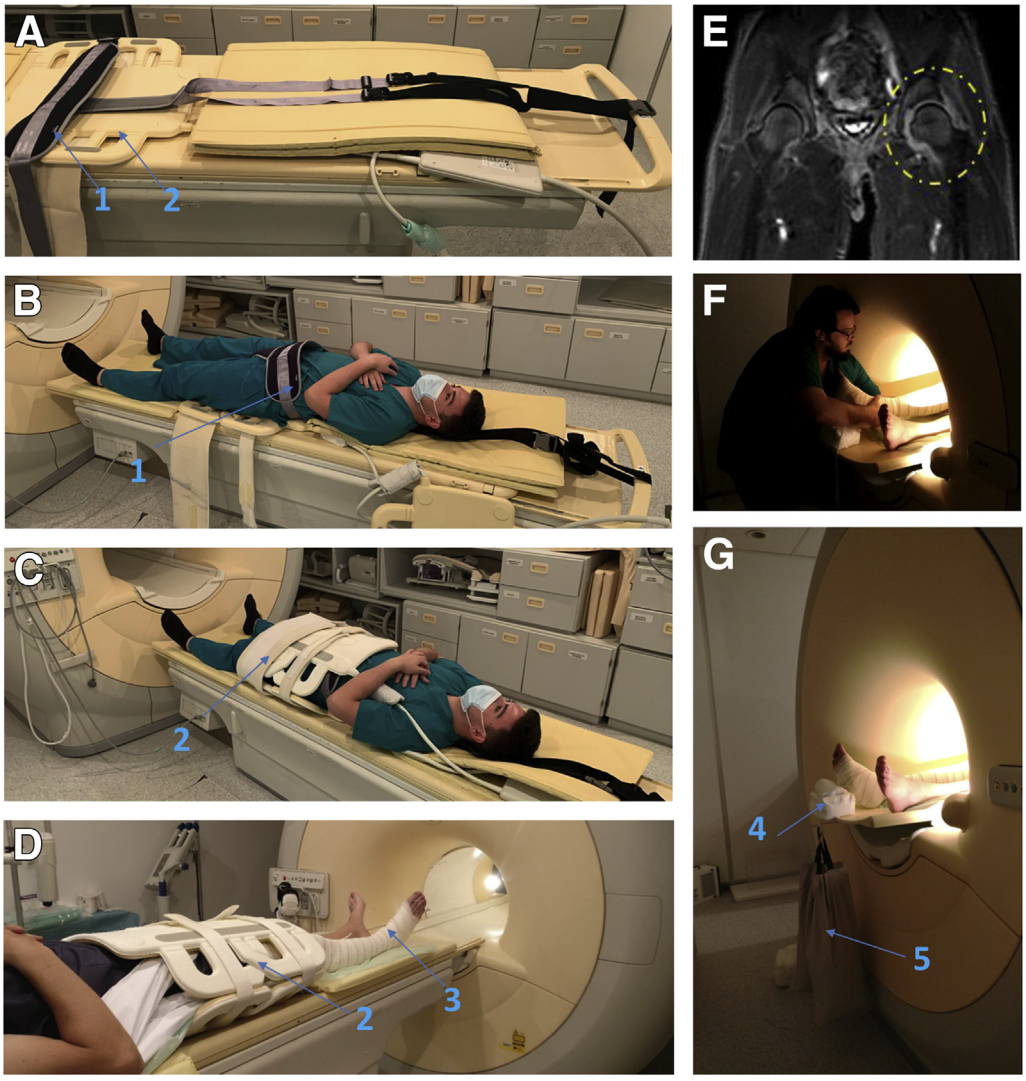

Fig 5. Imaging control procedure performed by direct/indirect very high field 3T resonance arthrography technique with specific morphological hybrid sequences for assessing the cartilage, at 12-15 months following surgery. (A–D) Before using the harness to separate the articular surfaces, we used opposite manual traction to fix the patient. (E) Difference between intravenous contrast uptake previous active exercises with indirect arthrography technique, after intravenous administration. (F) Manual traction maneuver to separate both sides of the joint, rotations, and traction from the popliteal gap. (G) Weight posterior 8-16-kg axial leg traction. 1) Harness, 2) 16 channel phased-array body coil, 3) traction above-knee bandage, 4) pulley, and 5) weight.

actual situation? At the last follow-up, patient satisfaction scored 86.6% (SD 16.4).

No patients had to change their work activity following the surgery, and all those who had stopped physical activity were able to resume it (Table 3).

The α angle values, the coverage angle, and the articular space in millimeters were determined preoperatively and in the last assessment of the surgery through radiography. The results are presented in Table 5, which shows a significant decrease in the α angle, with $P < .0001$. It is important to note that there was no worsening of the articular space measured in millimeters.

The Tönnis stage was maintained in 22 cases; one patient worsened by one stage, from stage II to stage III, and three patients improved, going from stage II to stage I (based on osteophyte disappearance, better joint space) (Fig 6).

Over a maximum postsurgical score of 100 on the scale, our average MOCART at 12 months was 87.8 (SD 8.3). Our results (Table 6) show that patients treated with a collagen matrix maintain a chondral defect filling aligned with the adjacent cartilage in 88% of the cases.

Good integration of the matrix with the subchondral bone was refreshed in 94% of the patients assessed. These findings indicate that the matrix adheres correctly to the surgically present grade IV chondral defect.

In 29.4% of patients, the repair tissue's surface was intact but presented some minor fibrillations or fissures of less than 25% of the tissue's thickness.

The subchondral lamina was found to be intact in 65% of the repaired cases, and we have only observed subchondral edema in 25% of them, which was mild <1 cm. Also, we measured the thickness of the repair

Table 2. MOCART (Magnetic Observation of Cartilage Repair Tissue) Score

Filled defect: amount of the defect filled and filling of the defect in relation to the adjacent tissue	Score Assigned
Aligned with adjacent cartilage	15
Hypertrophy compared to adjacent cartilage	10
Below the level of adjacent cartilage	
<50% adjacent cartilage	3
>50% adjacent cartilage	0
Cartilage interface: integration to adjacent cartilage limited to two planes	
Complete	10
Defect <50%	5
Defect >50%	0
Bone interface: integration of the tissue to subchondral bone	
Complete	10
Partial delamination	5
Complete delamination	0
Surface: condition of the repaired surface	
Intact	10
Damage depth <50%	5
Damage depth >50%	0
Structure: condition of the repaired tissue	
Homogeneous	10
Heterogeneous	5
Presence of continuity solution	0
Signal intensity: intensity of the repair compared with adjacent tissue	
Normal	10
Almost normal	5
Abnormal	0
Subchondral lamina	
Intact	5
Not intact	0
Osteophytes in the repaired cartilage	
Absent	5
Present	0
Bone edema: maximum size in relation to the repair	
Absent	10
Small <1 cm	5
Medium-sized <2 cm	3
Large: <4 cm	2
Diffuse	0
Subchondral bone	
Intact	5
Presence of granulation tissue	3
Presence of cysts	2
Effusion	
Absent	10
Mild	5
Moderate	3
Severe	0

tissue generated from the matrix in all our patients treated over an grade IV lesion and found a tissue with a mean thickness of 2.2 mm, somewhat smaller than the physiological acetabular superolateral chondral thickness of 3 mm, but in any case, showing a new filling of the previous defect (Fig 7).

Complications

No adverse events derived from the treatment were recorded during follow-up. As has been mentioned, two patients required joint replacement surgery THR (7%).

Discussion

The most important finding of this study was that the AMIC procedure with a liquid acellular type I collagen matrix was effective in the short-term for treating 2-4 cm^2 acetabular grade IV lesions. In 95% of the cases, clinical improvement was seen at 24 months following treatment (95% met the MCID), the range of motion, where significant IR differences were observed ($P = .0001$), as well as of perceived pain, based on the values of the VAS scale ($P < .0001$) and on the mHHS, with 22 out of 23 (95%) meeting the MCID and 23 (100%) meeting PASS. No patient had to modify their work activity, and the ones who practiced sports could all resume physical activity.

Moreover, from the radiological point of view, this matrix's application allowed to halt articular destruction progression, with the articular space's maintenance and not observing any increase in the Tönnis stage (Table 5).

Our series shows evident femoral deformity (preoperative α angle of 67.7), a known cause of acetabular outside-in chondral damage.[7–9] Most of the damage was presented in the superior and anterior part of the acetabulum (11:00−15:00 hours ±1 clock-wise) with 14 of our patients presenting with IV chondral size 4 cm^2 lesion.

The liquid acellular type I collagen matrix acted as a scaffold, facilitating the migration of autologous cells adjacent to the subchondral bone and the healthy cartilage. This filling process stimulates the chondral

Table 3. Number of Patients by Type of Physical Activity before Treatment

Type of Physical Activity	Patients (N)
1. Running	3
2. Soccer	2
3. Cycling	4
4. Martial arts	1
5. Gymnastics	2
6. Climbing	0
7. Others: swimming, walking, dancing ...	3
8. Paddle	1
Combination of various physical activities	
1, 2, 5	1
1, 3, 7	2
2, 3, 4	1
1, 2	1
1, 8	1
3, 7	1

Table 4. Changes in Range of Motion from Preoperative to the Last Follow-Up

Mobility	Preoperative	Last Examination	*P* Value
Flexion			
Mean	130.0	138.5	.0242
SD	14.1	7.5	
Range	90-140	110-150	
Flexoabduction			
Mean	63.8	67.8	.18277
SD	9.9	8.0	
Range	45-75	50-80	
Internal rotation			
Mean	14.7	30.0	.0001
SD	13.1	1.8	
Range	0-30	25-35	

matrix synthesis, showing high chondrogenic potential in other trials.[34]

Arthroscopy provided excellent visualization of the defect, which allowed for good conditions for the complete drying of the defect area before filling it with the acellular matrix. This procedure, combined with the matrix's adhesiveness and moldability characteristics, allowed the correct filling, hardening, and proper adherence of the matrix and complete coverage of the lesion.[35] There is no harvest site morbidity, and the operation can be performed in a single procedure. No cell complex expansion techniques are needed.

Concerning chondral lesions in patients with FAI, initial reports clearly show worse clinical outcomes, with decreased performance in the assessment scales in the medium-term and variable conversion rates to total hip arthroplasty (THA) compared with similar cohorts of patients with no chondral lesion FAI. Byrd et al.[36] obtained conversion rates to THA at 63 months in 88% of the patients with a chondral lesion at the time of arthroscopic surgery. Horisbeerger et al.[37] in a group of patients <50 years old with microfractures, obtained a THA conversion rate of 50% at three years' follow-up. McCarthy et al.[38] reported an OR of needing THA 3.6 times higher in patients more than 40 years old and an OR of 20 in the case of group III-IV Outerbridge acetabular lesion. These were longer follow-up studies, and probably the management, knowledge, and techniques in hip arthroscopy have significantly changed in the past 5-10 years; thus, it is not our intention to compare our results but to show how the presence of chondral lesions worsen the results.

In a systematic review, Kemp et al.[11] concluded that hip arthroscopic surgery outcomes are worse in the presence of chondral lesions, with increasing age and seriousness of the chondral lesions, as higher risk factors and faster progression to THA. Chahla et al.[10] reported at two-year follow-up about the prevalence of chondral injuries after hip arthroscopy surgery for FAI. They found group IV chondral defects in 49 patients in which microfracture treatment (MFx) was performed. Worse functional outcomes, lower satisfaction rates, and increased pain were reported compared to patients without chondral damage. In acetabular group IV chondral defect, their preoperative reported VAS 74.9 (SD15.6) and mHHS 56.5 (SD 13.9) were not so different from our preoperative VAS 7.6 (SD 2.1) and mHHS 62.8 (SD 14.3). In the last follow-up, their reported VAS 32.3 (SD 27.5) and mHHS 73.2 (SD 17.9) were worse compared to our VAS 1.4 (SD 1.2) and mHHS 95.8 (SD 8.1). In their report, five patients (out of 49) underwent THP compared with our two patients (out of 25), which are similar. No data were reported about the defect size. Treatment of the cartilage lesion was different. They performed microfracture vs. AMIC. This fact could explain this difference, according to Giordano et al.,[39] who carried out an 8-year follow-up study with 109 patients between 18 and 55 years, with acetabular 2-8 cm^2 grades III and IV chondral lesions (Outerbridge) that were treated by MFx and/or by AMIC. The AMIC group had better results with a mHHS improvement maintained through the eight-year follow-up period, and no patient required THA vs. 22% of the microfracture group.

On the other hand, Nakano et al.[40] in a systematic review analyzed more than 10 techniques published for chondral hip defect treatment, concluding that there was no evidence to support any of surgical technique as a superior method for treating cartilage injuries of the hip, so the differences abovementioned with Chahla could not be only due to the treatment applied.

In other reports, Fontana et al.[41] in a study with a larger number of patients and a longer follow-up, conducted a comparative analysis between AMIC and MFx and membrane-guided chondrocyte (MACI) techniques, observing no differences, but did not report any

Table 5. Radiographical Assessment of the Alpha and Coverage Angles, and of the Articular Space, Before Surgery and at 24 Months Following Implantation of the Acellular Collagen Mesh

	Presurgical		Postsurgical				
Variable	Mean	SD	Mean	SD	Variation (%)	SD	*P*
Angle α	67.7	10.5	44.1	4.9	34.8	11.8	<.0001
Angle of coverage	28.7	4.7	25.3	3.7	11.8	6.0	.0111
Articular space (mm)	4.00	.79	3.99	1.16	.25	2.57	.9735

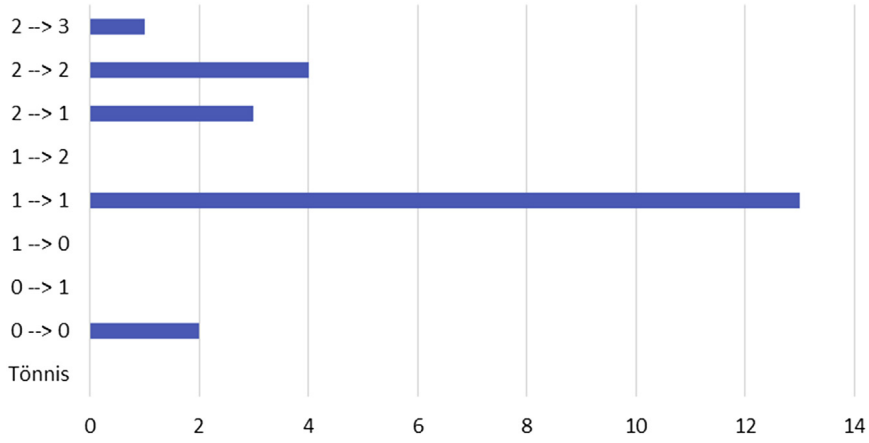

Fig 6. Tönnis changes after the surgery at the last follow-up.

radiological data on the outcomes of the patients treated. Thier et al.,[42] in a recent study with a liquid chondrocyte application in patients with a similar profile to our patients—the type of chondral lesion—obtained an improvement in all assessment scores at the one-year follow-up. However, they could not assess the quality of the generated tissue since they did not have a control MRI or a second review arthroscopy. The same issues can be found in the trials conducted by Fickert et al.[43] or Körsmeier et al.[44]

The morphological study with very high field 3T arthro-MRI allowed us to analyze the characteristics and integration of the generated tissue (MOCART). 94% presented good integration of the matrix with the refreshed subchondral bone. The MOCART tool shows two closely interrelated variables like the repair tissue signal's intensity with the adjacent cartilage and its internal signal homogeneity or lack thereof. 52.9% of the cases present a homogeneous signal, with the other half having a heterogeneous signal. However, this is not surprising, given that the alteration of the persistent signal has been observed in previous studies of other joints up to 24 months.

The very high field 3T MRI arthrography was a valuable tool for assessing cartilage repair, requiring a separation of the articular surfaces and multiplane high-resolution sequences for chondral assessment, ensuring a detailed analysis of the behavior of the tissue in articular cartilage repair[45] (Fig 7).

Moreover, from the radiological point of view, this matrix's application allowed to halt articular destruction progression, with the articular space's maintenance and not observing a significant increase in the Tönnis stage.

However, the efficacy of the MRI protocols and the MOCART score system for assessing the articular cartilage repair tissue used in this study allowed us to assess the patients without restoring to pathological anatomy.[46]

Notwithstanding the above, the data can be used as a basis for future studies using the same technique and preliminary data for a future long-term follow-up study of the patients included in this trial. More extensive studies with a more extended follow-up period are needed to verify the generated tissue's durability and correspondence with clinical results.

We have not been able to find another study in which an AMIC technique has been used for the treatment of high-grade chondral lesions through hip arthroscopic surgery, with an objective radiological analysis, both in terms of the overall radiological evolution of the joint and of the characteristics of the generated tissue, based on a MOCART score with very high field 3 Tesla arthrography.

Limitations

The study's limitations include the retrospective design with questions regarding recall bias, absence of a control group, selection bias, only short-term data, findings based on a small sample size, single surgeon, and different mHHS compared to other publications. Despite its advantages, the MRI could not show the composition of the cartilage repaired tissue, which can only be obtained through histological biopsies.

Conclusion

The liquid acellular collagen matrix implantation (AMIC) is a safe technique that shows good clinical and radiological outcomes in a 2-year follow-up in patients with femoroacetabular impingement and grade IV acetabular 2-4 cm^2 chondral defects.

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Table 6. Variables Assessed by Means of Arthro-MRI, Following the Items of the MOCART Score[33]

	Filled Defect				Cartilage Interface Integration to Adjacent Cartilage			Bone Interface Integration to Subchondral Bone		
Total *n* 26	Aligned with Adjacent Cartilage (15)	Hypertrophy Compared to Adjacent Cartilage (10)	Thickness >50% Adjacent Cartilage (3)	Thickness <50% Adjacent Cartilage (0)	Complete (10)	<50% (2)	Defect >50% (0)	Complete (10)	Partial Delamination (5)	Complete Delamination (0)
n	26	0	0	0	16	10	0	25	1	0
%	100	0	0	0	61.5	38.5	0	96.2	3.8	0

	Surface Condition of the Repaired Surface			Structure Condition of the Repaired Tissue			Signal Intensity Comparison with Adjacent Tissue		
	Intact (10)	Damage Depth <50% (5)	Damage Depth >50% (0)	Homogeneous (10)	Heterogeneous (5)	Presence of Continuity Solution (0)	Normal (10)	Almost Normal (5)	Abnormal (0)
n	12	14	0	15	11	0	9	17	0
%	46.2	53.8	0	57.7	42.3	0	34.6	65.4	0

	Subchondral Lamina		Osteophytes in the Repaired Cartilage		Bone Edema Size, Location in Relation to the Repair				
	Intact (5)	Not Intact (0)	Absent (0)	Present (5)	Absent (10)	Small <1 cm (5)	Medium-Sized <2 cm (3)	Large:<4 cm (2)	Diffuse (0)
n	21	5	26	0	22	4	0	0	0
%	80.8	19.2	100	0	84.6	15.4	0	0	0

	Subchondral Bone			Effusion			
	Intact (5)	Presence of Granulation Tissue (3)	Presence of Cysts (2)	Absent (10)	Mild (5)	Moderate (3)	Severe (0)
n	17	8	1	26	0	0	0
%	65.4	30.8	3.8	100	0	0	0

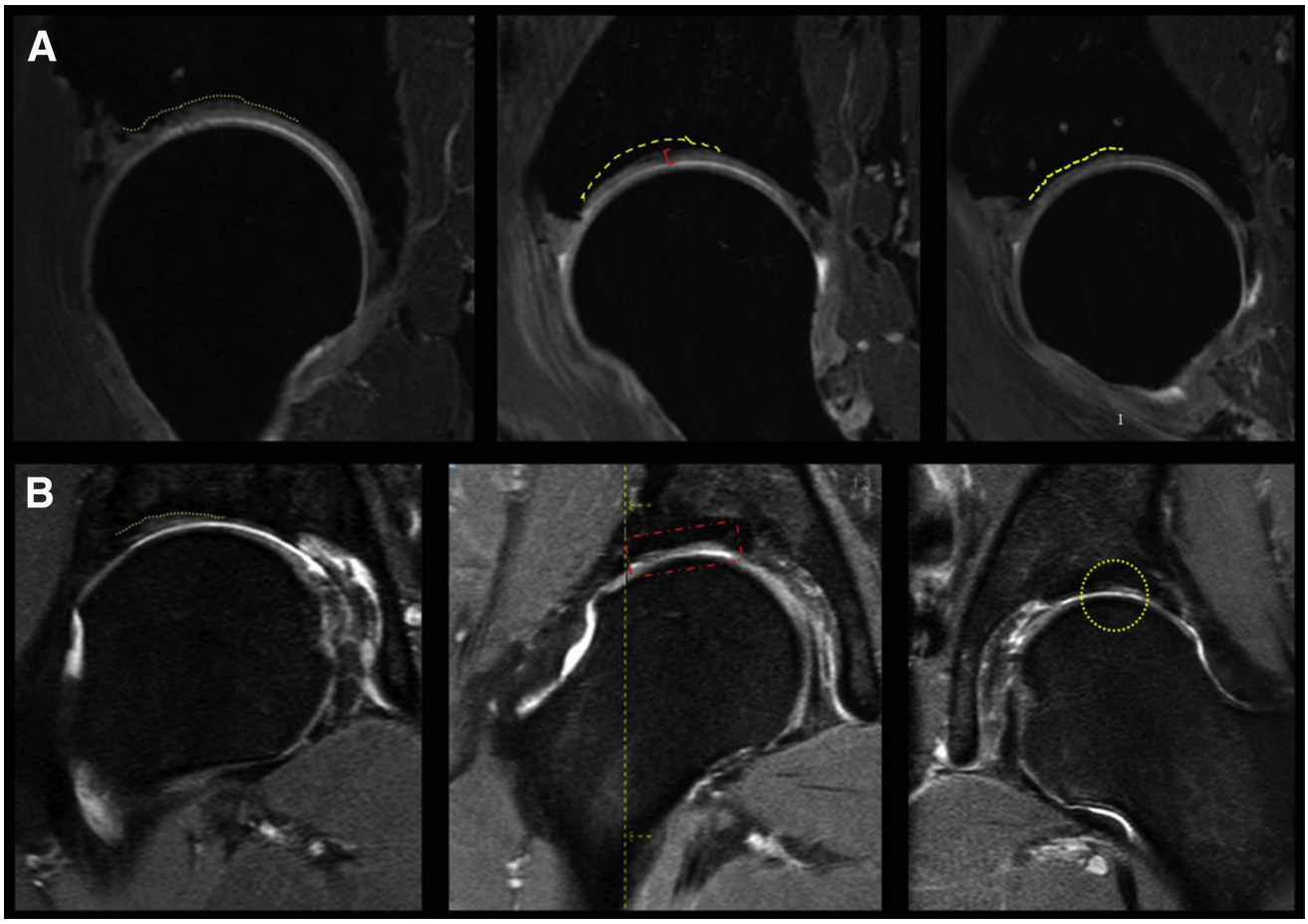

Fig 7. Right hip cellular collagen matrix implantation (AMIC) technique assessment by means of 3T magnetic resonance imaging (MRI) arthrography, manual decoaptation, and traction. (A) Left image, prior chondral defect filling, subchondral lamina abrasion, and central and right images, AMIC implant isointense to the adjacent tissue, homogeneous, aligned with satisfactory subchondral integration; (B) From left to right, tissue of the aligned AMIC implant, covered acetabular defect, signal of the generated tissue similar to the adjacent chondral tissue.

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