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The Extension–Thickness–Damage (ETD) score: a pre-operative hip MR arthrography-based classification to predict type of labrum surgery

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Abstract

Introduction Hip magnetic resonance arthrography (MRA) is the pre-operative imaging modality of choice in patients with labral damage, with several classifications of labral tears having been reported based on MRA findings. Nevertheless, none of the available classification systems allows the surgeon to predict before surgery how a labral tear could be treated. Our purpose was to develop a new MRA-based scoring system of labral tears to predict before surgery the treatment option more suitable for labral tears.

Materials and methods Forty-seven patients (29 males and 18 females; mean age: 35.9 ± 12.4) performed hip MRA for suspicious of femoroacetabular impingement and were afterwards subjected to arthroscopic treatment. Two musculoskeletal radiologists reviewed all pre-operative examinations and provided the Extension–Thickness–Damage score for each patient, based on Extension of tear, Thickness of labrum, and type of Damage. Chondral lesions grading was based on the arthroscopic findings according to Konan classification. For statistical purposes, patients were divided into two groups, depending on the type of treatment: labral repair or debridement. Mann–Whitney *U*, Chi-square, receiver operator curves, and Cohen kappa statistics were used.

Results 35/47 underwent repair, while 12/47 were debrided. In both groups, the median chondral damage was grade III, with no significant differences ($p = 0.439$). The median Extension–Thickness–Damage score in the repair group (6) was significantly lower ($p < 0.001$) than that in the debridement group (8). The highest diagnostic performance (area under the curve) of Extension–Thickness–Damage was 0.819. The inter-observer agreement was substantial in the evaluation of Extension ($k = 0.626$) and Thickness ($k = 0.771$), and almost perfect for Damage ($k = 0.827$). Higher scores of Extension and Thickness were more frequently associated with debridement ($p < 0.001$; $p = 0.0016$, respectively), with no significant differences on the basis of Damage parameter ($p = 0.284$).

Conclusions The MRA-based Extension–Thickness–Damage score could represent a helpful pre-operative tool, expressing the extent of the damage and its reparability before arthroscopy.

Keywords Magnetic resonance arthrography · Hip · Labrum · Tear · Arthroscopy

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Introduction

Labral pathology is one of the most common causes of hip pain and disability [1, 2]. The estimated prevalence of labral lesions ranges from 22 to 55% in symptomatic population [3]. Five causes of labral tears have been reported: (1) trauma, (2) femoroacetabular impingement (FAI), (3) capsular laxity/hip hypermobility, (4) dysplasia, and (5) degeneration [4]. The arthroscopic treatment of labral tears has substantially increased over the last years. Hip arthroscopy has shown to be safe with relatively common minor complications such as hematoma and temporary paresthesia due to traction neurapraxia, but rare major complications, which rate is decreased with increased surgeon's experience [5]. Moreover, as recently reported by Olach et al., hip arthroscopy does not seem to determine a significant progression of osteoarthritis on long-term follow-up [6]. Three surgical options exist for the management of labral tears: debridement, repair, or reconstruction. To date, whether the labrum is amenable to suture, repair or not is based on intra-operative findings as tear pattern, morphology, and quality of the labral tissue, as suggested by Philippon et al. [7].

Clinical outcomes of suture repair in patients with FAI seem to be superior in comparison to labral debridement [8, 9]. Krych et al. reported better functional outcomes in female patients with FAI after labral repair than labral debridement [10]. Labral reconstruction is an alternative option despite being a more time-consuming, invasive, and expensive procedure, besides not widely accepted by the surgeon community [11]. Thus, it might be helpful for surgeons and patients to recognize pre-operatively which labral tear needs to be repaired, debrided, or reconstructed at the moment of surgery.

Hip magnetic resonance arthrography (MRA) is the pre-operative imaging modality of choice in patients with labral damage [12–14]. MRA involves intra-articular injection of diluted gadolinium contrast into the hip joint, with the benefit of capsular distention and improved visibility of anatomical structures [15]. MRA has demonstrated sensitivity of 69–100% for the detection of labral tears [16].

The types of labral tears have been classified based on MRA or arthroscopic findings. Czerny et al. described the MRA classification of labral tears in three stages [17]. Lage et al. arthroscopically divided the labral tears in radial flaps, longitudinal peripheral tears, radial fibrillated tears, and unstable tears [18]. Beck at al. described different arthroscopic pattern of labrum damage: degeneration, full-thickness tear, detachment, and ossification [19]. Neumann et al. introduced a semi-quantitative scoring system based on MRA findings, reporting a correlation between labral tears, cartilage loss, and bone marrow edema [20]. These classifications provide useful pre-operative information regarding the status of the labrum and the type of tear. Regarding the Czerny classification, it was reported that patients with stage II and III labral tears have not significantly different clinical outcomes after arthroscopic debridement, reducing the potential prognostic role of this classification system [21]. Furthermore, it does not correlate well with arthroscopic Lage classification [22]. Finally, available classification systems scarcely allow the surgeon to help predicting how a labral tear could be treated before surgery.

Thus, our purpose was to develop a new MRA-based scoring system of labral tears to help orthopedic surgeons to predict, before surgery, the treatment option more suitable for a labral tear in patients with FAI.

Materials and methods

Population and study design

Local ethics committee approval was obtained and patients' informed consent was waived. Details potentially disclosing the identity of the involved subjects were omitted. Forty-seven consecutive patients (29 males and 18 females; mean age: 35.9 ± 12.4) who performed hip MRA for suspicious of FAI and were afterwards subjected to arthroscopic treatment were included in this evaluation. Patients were selected according to the following inclusion and exclusion criteria:

Inclusion criteria

- skeletally mature (> 18 years old);
- patients who performed standardized hip MRA and consequent arthroscopy between May 2013 and May 2015;
- diagnosis of FAI with labrum damage;
- arthroscopic labral debridement or repair.

Exclusion criteria

- FAI with normal labrum at MRI;
- previous hip surgery;
- inadequate MRA images;
- complete ossification of the labrum;
- Hip Dysplasia (defined as a Lateral Center-Edge Angle of less than 25° and a Sharp Angle of more than 38°).

MRA

Intra-articular injection of contrast agent was performed by the same radiologist under ultrasound-guidance using a convex probe with anterior approach [23]. Patients were positioned supine with the hip under investigation slightly

intra-rotated. After careful skin disinfection, a 20 G needle was then inserted into the joint space and up to 20 ml of 0.002 mmol/ml of gadopentetic acid (Magnevist pre-filled syringes, Bayer, Germany) were injected after continuous ultrasound monitoring. After the procedure, the patient's hip was gently intra- and extra-rotated to better distribute the contrast into the joint capsule. MRA was performed within 15 min from contrast agent injection using a 1.5-T system (Magnetom Symphony, Siemens Medical Solution, Erlangen, Germany) equipped with a 40 mT/m gradient power and a dedicated phased-array surface coil. Imaging protocol included three planes (axial, coronal, and sagittal) turbo spin-echo proton density fat-saturated sequences, transverse turbo spin-echo T1-weighted sequence, and a 3D sequence Dual-echo Steady State (TR/TE = 17/6 ms, slice thickness = 0.8 mm, and isotropic voxel = 0.8 × 0.8 × 0.8 mm). This last sequence was used to assess the Extension–Thickness–Damage (ETD) score.

Build of the Extension–Thickness–Damage (ETD) score and image analysis

The ETD score was developed and shaped on three fundamental prognostic parameters: extension of the damage (E), thickness of the labrum (T), and type of damage (D). These factors influence the choice of treatment and express the reparability of the labrum. The three parameters were defined as follows:

E = extension of labrum damage. Tears can be located dividing the acetabulum in different sections or using a clock-face representation. Similarly to what happens for the glenoid labrum [24], 3 o'clock is always located on the anterior side of the acetabulum. Considering the regions usually involved into labral tears, we divided the supracetabular area from anterior (3 o'clock) to posterior regions (9 o'clock), and we obtained four sections: anterior, antero-superior, postero-superior, and posterior (Fig. 1) [11]. One point was assigned for each involved section. The more section involved, the more severe the lesion.

T = thickness of the acetabular labrum. The smaller the size of the damaged labrum, the less tissue is amenable to be repaired, which often leads to debridement. Using multiplanar reconstructions, measurements of the labrum thickness were performed, considering the perpendicular axe to the acetabular bone and labral surface at 10, 12, and 2 o'clock. The section that corresponds with the labrum at 12 o'clock position on a clockwise is easily recognized on the sagittal image as the midportion of the supracetabular area. Then, the labrum at 10 and 2 o'clock can be identified by rotating the references 60 degrees posteriorly and anteriorly, respectively. An average of these three measurements was calculated and a score was assigned as described below:

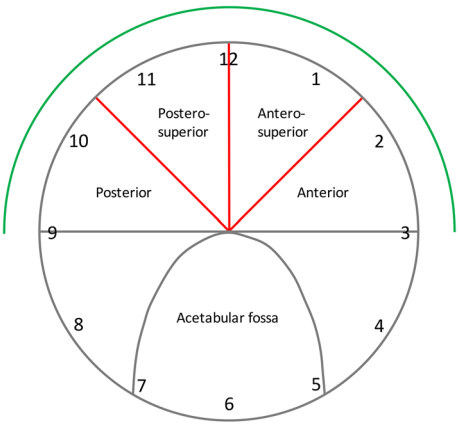

Fig. 1 Scheme of the supracetabular area from anterior (3 o'clock) to posterior regions (9 o'clock) divided into four sections: anterior, antero-superior, postero-superior, and posterior

- T1: thickness ≥ 8 mm = 1 point;
- T2: thickness between 5 and 8 mm = 2 points;
- T3: thickness ≤ 5 mm = 3 points.

D = damage. This parameter considered the type of labral lesion [21]:

- D1: partial or full-thickness tear, generally represented by a linear high signal in the labrum, = 1 point;
- D2: degeneration, which appeared as diffuse high signal in the labrum = 2 points;
- D3: combination of partial/full-thickness tear and degeneration = 3 points.

The more complex the type of damage, the less tissue is viable for an efficient repair [11].

The sum of E + T + D parameters generated a score ranging between three and ten points: the higher the score, the more severe the lesion. The ETD score is resumed in Table 1 and the scheme of labrum parameters for the ETD score is reported in Fig. 2.

All pre-operative MRAs were retrospectively reviewed and an ETD score was assigned to each patient, as below reported, by two musculoskeletal radiologists: one with 15 (R1) and one with 4 years (R2) of experience in interpreting hip MRA, respectively. Both radiologists were blinded respect to clinical data and the arthroscopic treatment.

Hip arthroscopy

Hip arthroscopy was performed by one orthopedic surgeon with 15 years of experience in hip arthroscopy, with the patient in a supine position on a fluoroscopic fracture table. The procedure was carried out under combined general/

Table 1 Scheme of ETD (Extension–Thickness–Damage) score

ETD score (range 3–10 points)		
E = Extension (4 points)	T = Thickness (3 points)	D = Damage (3 points)
Labrum damage involvement	*Labrum thickness*	*Type of labrum damage*
1 quadrant = 1 point	≥ 8 mm = 1 point	Tear = 1 point
2 quadrants = 2 points	5–8 mm = 2 points	Degeneration = 2 points
3 quadrants = 3 points	≤ 5 mm = 3 points	Tear + degeneration = 3 points
4 quadrants = 4 points		

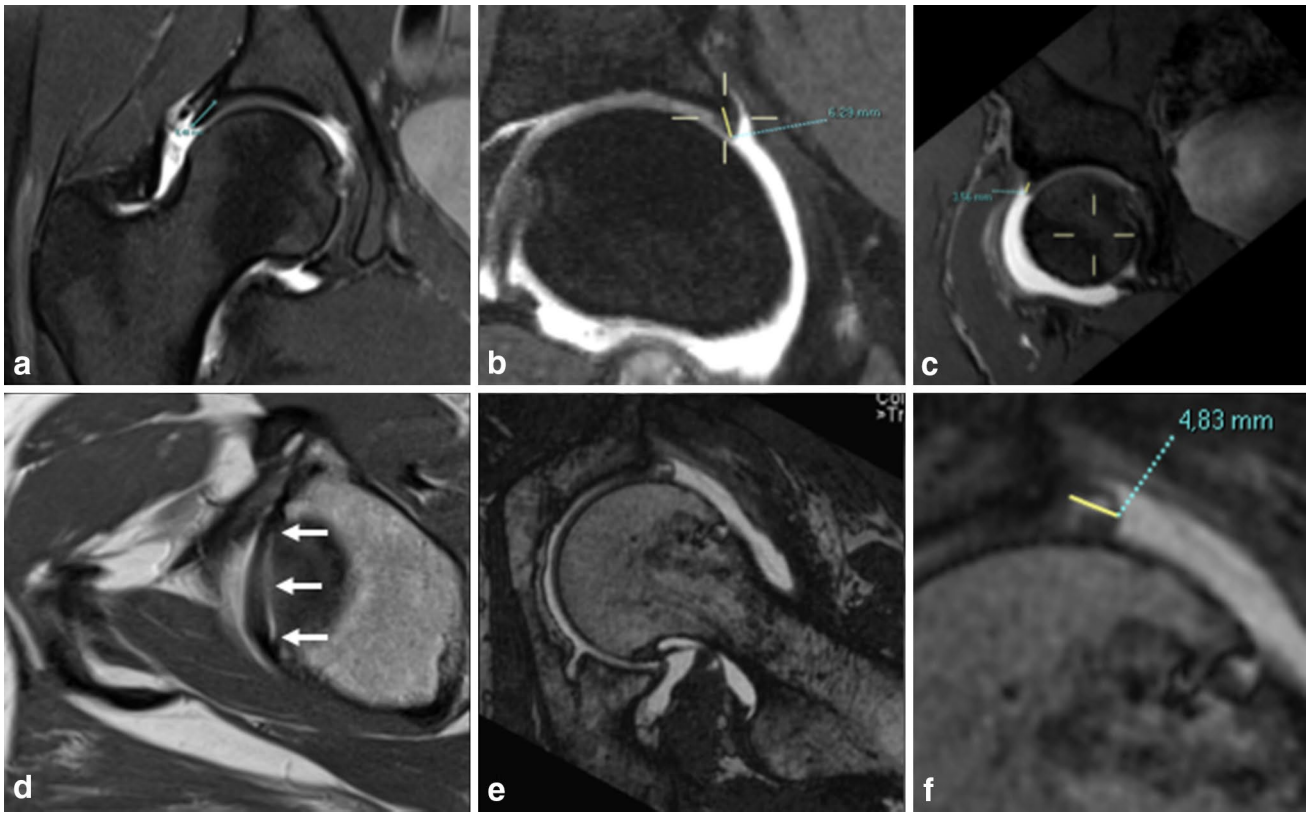

Fig. 2 Scheme of labrum parameters for the ETD score, respectively. **a** Measurement of the labrum at 12 o'clock position with a T score = 1 (teal line; thickness > 8 mm) and **b** T score = 2 (yellow line; thickness 5–8 mm); **c** measurement of the labrum at 10 o'clock position with a T score = 3 (yellow line; thickness < 5 mm); **d** full-thickness tear at chondrolabral junction (D score = 1), with an involvement of the antero-superior and postero-superior sections (E score = 2); **e, f** partial thickness tear of a degenerated labrum (D score = 3) with a T score = 3 (yellow line; thickness < 5 mm), respectively

spinal anesthesia with neuromuscular blockade, necessary to guarantee complete muscle relaxation.

Central and peripheral compartments of the hip joint were explored through the anterolateral, mid-anterior, and rarely posterolateral portals. A distal anterolateral accessory portal was performed in case of anchor placement for labral repair.

Routine arthroscopy was carried out with the inspection of the central compartment first with traction and then the visualization of the peripheral compartment without traction. Proximal femoral osteoplasty or acetabular rim trimming or both were performed based on the diagnosis of cam, pincer, or mixed-FAI, respectively [22]. Chondral lesions were described in 4 degrees based on the arthroscopic morphology of the damage, using the classification introduced by Konan et al. [25]. The labrum was either debrided or repaired depending on the type of lesion, thickness, and quality of labral tissue as seen during the procedure.

Statistical analysis

For statistical purposes, patients were divided into two groups, depending on the type of treatment: repair or debridement. The ETD score was considered as a continuous variable and was expressed in terms of median and interquartile range (IQR). The comparison of the medians of the two groups was performed using the Mann–Whitney

U test. The distribution of each single parameter (E, T, and D) was also considered independently and the differences between the two groups were evaluated through the Chi-square test. The receiver operator characteristic (ROC) curve was then constructed calculating sensitivity and specificity associated with each ETD score. Accuracy of the ETD score was also calculated as the area under the curve (AUC). In clinical practice, a diagnostic test is considered acceptable if its AUC is ≥ 0.8. Inter-reader reproducibility between the two radiologists was estimated by a statistic working in our team, using the quadratically weighted Cohen kappa (k) statistics. In particular, it was initially estimated separately on the three different parameters, and then, it was evaluated on the overall ETD score. The k coefficient ranges from 0 (when there is no agreement beyond chance) to 1 (indicating total agreement). A k of 0.2 is considered poor, between 0.21 and 0.4 fair, 0.41–0.6 moderate, 0.61–0.8 substantial, and more than 0.81 almost perfect [26]. A p value lower than 0.05 was considered as statistically significant. The SPSS Statistics software (IBM, USA) was used for statistical analysis.

Results

Out of 47 patients, 35 (74%) underwent repair, while 12 (26%) were debrided. The repair group counted 21 males and 14 females, with median age of 28 years (range 18–56 years, IQR 22–38 years). The median delay between MRA and arthroscopy was 238 days (range 58–672 days, IQR 183–297 days). The debridement group was composed of 8 males and 4 females, with median age of 35 years (range 19–55 years, IQR 26–43 years). The median delay between MRA and debridement procedure was 201 days (range 105–567 days, IQR 136–325 days). The two groups were homogeneous considering age ($p = 0.58$).

In the repair group, 14/35 (40%) presented grade I chondral lesions, 3/45 (9%) grade II, 12/35 (34%) grade III, and 6/35 (17%) grade IV. In the debridement group, 2/12 (17%) had grade I cartilage damage, 1/12 (8%) grade II, 7/12 (58%) grade III, and 2/12 (17%) grade IV. In both groups, the median chondral damage was grade III. No significant difference was found between cartilage grades in the two groups ($p = 0.439$).

The labral tears involved the anterior section in 35 patients, the antero-superior in 38, the postero-superior in 8, and posterior in 4. The median ETD score for both readers in the repair group (6, IQR 5–7) was significantly lower ($p < 0.001$) than that in the debridement group (8, IQR 6–9). The receiver operator characteristic curve to discriminate between debridement and repair procedures revealed that the optimal cut-off ETD score value was 7 with 81.9% accuracy (area under the curve) for R1 (Fig. 3) and 80.1% for R2.

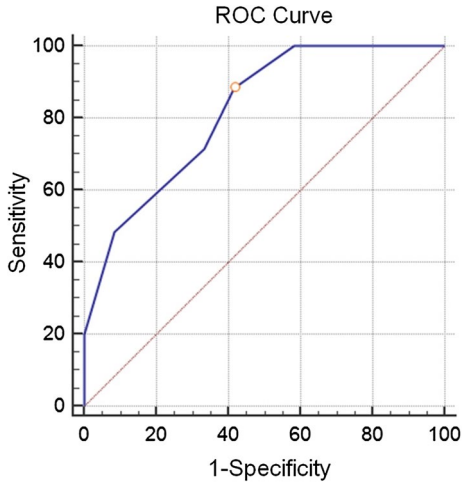

Fig. 3 The receiver operator characteristic curve to discriminate between debridement and repair procedures revealed that the optimal cut-off ETD score value was 7 with 81.9% accuracy (Area under the curve) for R1 and 80.1% for R2

Table 2 Separate results for Extension (E1–E4), Thickness (T1–T3), and Damage (D1–D3) scores at magnetic resonance arthrography in respect to suture or debridement procedure performed during arthroscopy

	Radiologist 1		Radiologist 2	
	Suture	Debridement	Suture	Debridement
Extension				
E1	21	1	15	1
E2	14	5	18	6
E3–E4	0	6	2	5
Thickness				
T1	0	0	0	0
T2	22	3	29	4
T3	13	9	6	8
Damage				
D1	11	3	10	2
D2	15	3	16	5
D3	9	6	8	5

Values indicate number of patients. Overall, $n = 35$ patients underwent labrum suture, while $n = 12$ patients underwent debridement

Reproducibility analysis showed a substantial agreement between R1 and R2 in the evaluation of Extension ($k = 0.626$) and Thickness ($k = 0.771$) parameters, and an almost perfect agreement in the evaluation of Damage ($k = 0.827$). The agreement for the overall ETD score was moderate ($k = 0.550$).

Then, each single parameter of the ETD score was considered separately for its association with debridement or repair procedure and full data are reported in Table 2. Higher scores of Extension were more frequently associated with

debridement choice for both readers (R1: $p < 0.001$; R2: $p = 0.023$). Furthermore, in the case of Thickness parameter, higher scores were more often related to debridement (R1: $p = 0.0016$, R2: $p = 0.019$). The difference of the distribution was not statistically significant between repair and debridement when considering the Damage parameter (R1: $p = 0.284$; R2: $p = 0.575$).

Figure 4 shows a case from our study population.

Discussion

We developed a new pre-operative score which may help predicting the surgical procedure of labrum in patients who undergo hip arthroscopy. A threshold of 7 seems to be able to differentiate patients who will undergo surgical debridement from those who will undergo surgical repair.

The labrum has been demonstrated to play a fundamental role in lubrication, stability, and kinematics of the hip [27–29]. Ferguson et al. showed that the labrum acts as a seal, preserving the lubrication of the joint by creating a negative intra-articular pressure, distributing stresses on cartilage layers, and decreasing friction [30]. In case of labral absence or damage, the articular cartilage surfaces compress 40% more quickly and progression to osteoarthritis is faster [31]. However, the decision to repair or debride the labrum is commonly taken intra-operatively after checking the labrum status. Thus, if an orthopedic surgeon knows a priori that a labrum is not repairable, he may also decide to reconstruct the labrum with a sample of patient's fasciae latae, through a new longer surgical incision, or a tendon allograft that may not be promptly available if not planned. We note, however, that there is a hot debate on this topic in literature and that there is no consensus about the best treatment options in these patients. What is known is that the extension of the damage, thickness of the labrum, and type of tear type are important keys guiding the intra-operative choice of the best treatment option [9]. In this setting, MRA might play a central role in the pre-operative study of hip labral damage [1, 32]. However, there has been limited utilization of MRA for correlation of labral tear pattern to the surgical procedure. It is important to underline that the previous MRA scores have demonstrated to give useful information for the orthopedic surgeon. For instance,

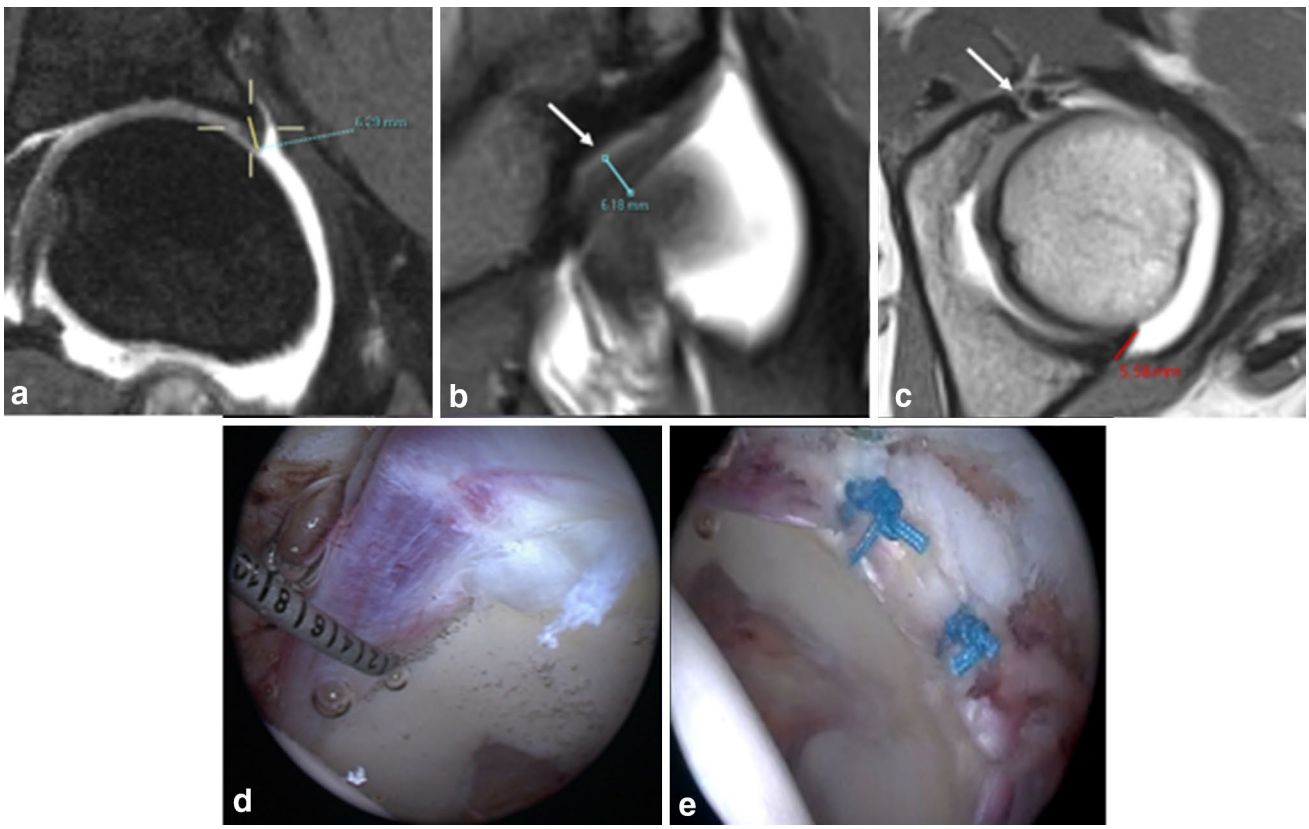

Fig. 4 Hip MRA and arthroscopy of a 32-year-old man. Measurement of the labrum at 12 o'clock position (**a**, yellow line), 2 o'clock position (**b**, teal line), and 10 o'clock position (**c**, red line), with an average thickness of 6 mm (T score = 2). The tear (**b, c**, white arrow) is located in two sections, the anterior and antero-superior labrum (E score = 2), without degeneration of the labrum itself (D score = 1). E + T + D (2 + 2 + 1) score = 5. The patient underwent arthroscopy and the labrum was repaired (**d, e**)

Neumann et al. graded the labrum for a change in signal or a simple or complex tear and included in their MRA scoring system also the extension of bone marrow edema and size of cartilage lesions [20]. Instead, Czerny classification provides pre-operatively helpful details on the shape of the labrum and extension of contrast material into the labrum [17]. Nevertheless, Freedman et al. assessed the prognostic value of the MRA Czerny classification, concluding that patients with Czerny stage II and III labral tears did not have differences in clinical outcomes after arthroscopic labrectomy [33]. Furthermore, the radiological Czerny classification of labral tears does not correlate with arthroscopic findings as described by the Lage classification. In addition, the previous studies have not demonstrated the capability of these scores to predict the type of surgical approach in advance. In this setting, the ETD score might have a substantial clinical relevance potentially giving to MRA the interesting pre-operative role to help the orthopedic surgeon to predict exactly the best arthroscopic treatment of labral tears. Indeed, we observed significantly higher ETD scores in patients who later underwent debridement than in those who underwent repair, with an optimal threshold of 7 yielding 81.9% accuracy to differentiate the two groups. The diagnostic performance higher than 0.8 and similar for both reviewers also witnesses that this score may be of help. We think that this novel score, besides showing an interesting correlation with the surgical approach, enables to obtain a more comprehensive evaluation of the labrum status than the previous scores giving a more reliable snapshot of the surgical target to the orthopedist.

The reproducibility of diagnostic scores is crucial to allow for clinical application of these tools [34]. According to our data, the reproducibility of ETD score is high, particularly for what concerns the single parameters. Reproducibility of the total score is, however, slightly lower, as expected when multiple factors are combined. The introduction of this pre-operative classification may represent an important step for the communication to the patient with labrum damage, giving the orthopedic and radiologist an immediate perception of the extent of the labral damage, as the Snyder classification does in rotator cuff tears [35].

The E and T parameters showed a significant correlation between debridement and increasing score when considered separately. Conversely, the D parameter had a different correlation with the possibility of debridement or repair when compared to E and T. Literature is scarce about labrum anatomic variation and degeneration related to FAI: MRA demonstrated not to be so accurate to distinguish a histologically-proven degenerated labrum [36]. This limitation of MRA technique for labral degeneration detection could explain this lack of correlation of the D parameter. On the other hand, the Extension parameter may be considered as an indirect value of labral degeneration. A wider labral lesion is clearly correlated with a more severe and lasting impingement pathology and, with a reasonable probability, with an irreparable labrum. It should be taken into account that bigger labrum width, although in our ETD score is a good prognostic parameter, may also be at an increased risk of degenerative changes, like in the case of a hypertrophic labrum encountered in dysplasia. Nevertheless, the feature "degeneration" is included in the Damage parameter. Clearly, the different parameters are not independent of one another, but impact in a different way on the choice debridement versus repair. Moreover, although it is true that a degenerated labrum with nonviable tissue should deserve debridement, a small and stable tear of a minimally degenerated labrum could be treated with repair. This could be another reason which partly explains the lack of significant difference in the distribution between repair and debridement when considering the Damage parameter.

It might be postulated that higher ETD grades could be related to a worse prognosis of a mid- /long-term follow-up, given that higher ETD score leads to higher risk of labral debridement, which is known to be associated with worse clinical and functional outcomes [8–10, 37]. Further studies or mid-term follow-up of our patients may be warranted.

Limitations of the present study are mostly attributable to its retrospective design and small sample size. However, significant differences were still found between the two groups of treatment. Larger prospective clinical trials are needed to confirm and validate these preliminary results. The long wait time between MRA and surgery could represent another limitation of the study: the characteristics of the labrum may have worsened or changed during this time. The long time intervals between MRA and surgery are related to the long waiting list in our institution, which is a referral center for hip arthroscopic procedures. Then, we did not evaluate the accuracy of pre-operative MRA in detecting the labral shape and damage, which could have given more strength to our score, but this was beyond the purpose of the study, also because the accuracy of MRA has been previously demonstrated by several studies with larger sample size. Furthermore, the lack of patients with labrum > 8 mm cut-off is a consequence of the exclusion criterium "hip dysplasia". If hip dysplasia would have been considered in the inclusion criteria, it is clear that such higher values would have been reached. Finally, we did not use radial reformats which have been reported to be a reproducible tool to enhance the evaluation of the cartilage and labrum in hip MRA. However, we preferred to use multiplanar reconstructions of the 3D sequence Dual-echo Steady State to detect and localize labral tears, modifying the orientation of the slices to better identify the lesion. Although some authors have demonstrated that radial imaging allows better identification of femoral cam deformity and evaluation of the antero- and postero-superior sections of the hip joint, controversial

results have been achieved in the previous studies regarding the added value to detect labral tears, with some authors considering radial reformats not helpful [21]. Moreover, radial imaging can be time-consuming, difficult to set up for technologists, and is not widely applied in imaging protocols [14], and thus, we believe that ETD score could be easier to obtain and with a widespread application through multiplanar reconstructions.

In conclusion, labral damage is a common condition in patients suffering from FAI. Currently, there is no classification able to pre-operatively predict the best treatment option for the labral damage before hip arthroscopy. The MRA-based ETD score could represent a possible solution for this question, expressing the extent of the damage and its reparability. Further studies are needed to confirm these preliminary reports and validate the accuracy of this score in the clinical practice, as well as to validate its clinical implications.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent For this type of study, formal consent is not required.

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