



# Reliability and validity of preoperative MRI for surgical decision making in chronic lateral ankle instability

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## Abstract

**Purpose** To evaluate the value of analyzing the anterior talofibular ligament (ATFL) on preoperative MRI as a decision-making tool to determine the surgical technique in patients undergoing surgery for chronic lateral ankle instability.

**Methods** A retrospective study of prospective data was performed. All patients who underwent surgery between 2013 and 2016 for arthroscopic stabilization of the ankle were included. The ATFL was evaluated on preoperative MRI including axial T2-weighted images by two readers who were blinded to arthroscopic results. The arthroscopic evaluation, which was considered to be the reference examination, was performed by one senior surgeon. The main judgment criteria were two features of the ATFL: (1) absent or thin (< 1 mm thick) and (2) detached or thickened (> 3.2 mm in diameter) with or without a high intensity intraligamentous signal. Inter- and intraobserver reproducibility was evaluated by the kappa coefficient (*k*), and parameters of the diagnostic accuracy of preoperative MRI were analyzed.

**Results** Twenty-two patients were included, 15 men/7 women mean age  $30.3 \pm 9.5$  years. Fourteen patients (63.6%) underwent arthroscopic repair of the ATFL (Broström–Gould technique) and 8 patients (36.4%) an arthroscopic anatomical reconstruction of the ATFL. Intraobserver reproducibility of MRI findings was substantial (*k* = 0.68) and interobserver reproducibility moderate (*k* = 0.55) to nearly perfect (*k* = 0.87). Agreement between MRI and arthroscopic findings was substantial (*k* = 0.70). Diagnostic parameters of preoperative MRI were good for both observers: Se = 85.7–87.5%, Sp = 86.7–92.9%, PPV = 75–87.5%, NPV = 92.9%, and classification of patients was good = 86.4–90.9%.

**Conclusion** Preoperative MRI of the ATFL is a reliable and valid decisional tool to choose the surgical technique for stabilization of chronic lateral ankle instability.

**Level of evidence** Level II; Diagnostic study—development of diagnostic criteria on the basis of consecutive patients.

**Keywords** Chronic lateral ankle instability · Anterior talofibular ligament · Arthroscopy · Ligament repair · Anatomical reconstruction · Surgical decision making

## Introduction

Ankle sprains are the most frequent injuries of the lower limb in athletic patients [7, 28]. Although in most cases the outcome of ankle sprains is favorable with conservative treatment [1, 11], 20–40% progress to chronic instability

with no confirmed relationship with the severity of the initial injury. The anterior talofibular ligament (ATFL) is the most frequently injured ligament in sprains, followed by the calcaneofibular ligament (CFL) and posterior talofibular ligament (PTFL) [26].

MRI is frequently used in the evaluation of chronic ankle instability, making it possible to determine the extent of ligament damage and the presence of associated injuries. However, its use remains controversial because it only identifies the damage to the ligaments without providing information on their mechanical properties and dynamic behavior [13, 16, 18, 25].

Surgical treatment can be an option in patients with chronic ankle instability in whom appropriate conservative treatment has failed after more than 6 months. Nearly 80

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surgical techniques have been described for the treatment of chronic ankle instability, with generally, repair techniques in cases with sufficient remaining ATFL tissue (tightening of capsuloligamentous structures with or without reinforcement) and ligament reconstruction when the ATFL is considered to be irreparable (anatomic or not, with tendon grafts) [9]. In the past few years, the value of arthroscopic repair and anatomic reconstruction techniques have been confirmed to stabilize the ankle and at the same time to evaluate and treat frequently associated lesions, which may determine the final outcome [12, 27]. However, there are no clearly established preoperative criteria, in particular imaging results, to choose between repair and reconstruction of the injured ligament. The choice often depends upon the experience and practices of the surgeon. Validation of decision-making criteria would make it possible to plan the surgical procedure under the best possible conditions and inform the patient of these choices before surgery.

The main goal of this study was to evaluate the value of preoperative MRI as a tool to evaluate the ATFL when deciding upon the choice of surgical technique in patients being treated for chronic lateral ankle instability. The hypothesis of this study was that an absent or thin ATFL on MRI was predictive of poor-quality remaining ligament tissue and should be an indication for ligament reconstruction with a graft.

## Methods

### Study design

This study followed the STARD (Standards for Reporting of Diagnostic Accuracy) guidelines [2]. It was based on a retrospective analysis of prospective data. Patients were informed before surgery that one or another type of procedure might be performed. Patient consent was obtained.

### Selection criteria

All the patients operated in our unit for chronic instability of the ankle between 2013 and 2016 were included in the study. The indication for surgery was based on clinical instability that had not responded to appropriate conservative treatment after at least 6 months, systematically including a protective brace and proprioceptive rehabilitation and, in certain cases infiltrations. Chronic ankle instability was defined by the patient feeling that the ankle was not normal, associated with numerous other symptoms such as recurrent sprains, pain, swelling, restricted activity or anterolateral impingement resistant to the infiltration test (ultrasound-guided anterolateral corticosteroid infiltration), with a history of an ankle sprain preceding the symptoms of instability.

Exclusion criteria were stabilization of the ankle by open surgery (because of a change in the practices in the unit) and incomplete MRI results.

### Preoperative MRI in the assessment of the ATFL

Preoperative 1.5 Tesla MRI results were analyzed twice, several days apart by two independent observers who were trained in musculoskeletal imaging and blinded to the arthroscopic results.

We used an Apple® platform with a Mac OS X operating system and free access Osirix 3.5.1 software (University of Geneva, Switzerland), developed by Rosset [20] and that can be downloaded on internet.

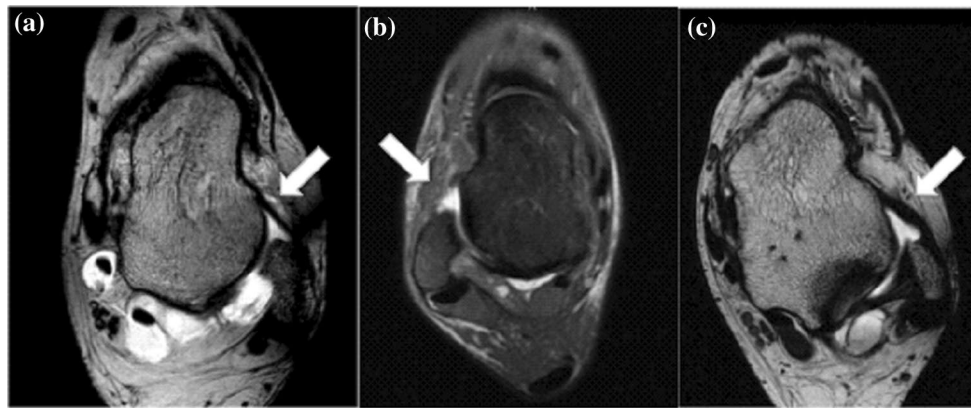
The ATFL was analyzed on axial T2-weighted MRI sequences. It is normally seen as a linear structure, with low signal intensity on T2-weighted images. ATFL injury, which is always found in chronic instability, has been well described in several studies [3, 10]. Lesions are classified into 4 categories: (1) ATFL absent; (2) thin ATFL (< 1 mm in diameter); (3) normally thick ATFL (1–3.2 mm) but that appears stretched, irregular or wavy; and (4) a thickened ATFL (> 3.2 mm in diameter) with or without an increase in intraligamentous signal intensity. It was considered that an absent or thin ligament could not be repaired and a normally thick or thickened ligament could be repaired. (Fig. 1).

### Reference examination: peri-arthroscopic assessment of the ATFL

The arthroscopic assessment was performed by a single surgeon, experienced and specialized in ankle surgery, and was the reference examination in this study. The surgeon had not measured the thickness of the ATFL on MRI before the intervention.

All patients underwent arthroscopy in our hospital in the dorsal decubitus position under general anesthesia. First, anterior arthroscopy of the ankle was performed with the foot positioned vertically in dorsiflexion without traction. A 4.5-mm scope was inserted into anteromedial portal no. 1, and anterolateral portal no. 2 was created by transillumination. After debriding the lateral groove with a shaver, the residual ATFL as well as the fibular and talar insertions were exposed and tested with a hook probe and a grasper, to classify the ligament as: (1) absent or thin or (2) detached but normal or thickened.

The surgical stabilization technique was decided depending upon the following features: a thickened ligament whose quality seemed to be good on palpation was an indication for repair by the arthroscopic Broström–Gould technique (tightening and reinforcement with the extensor retinaculum); or the absence of or a poor-quality ligament was an indication



**Fig. 1** Evaluation of the ATFL on axial T2-weighted images **a** normal ATFL (diameter = 1–3.2 mm), **b** absent ATFL, **c** thickened ATFL with curved contours (diameter > 3.2 mm)

for anatomical ligament reconstruction with gracilis autograft (allowing ATFL and CFL reconstruction) [8].

## Surgical techniques for ankle stabilization

### Modified Broström–Gould technique

After testing the ligament, a third instrumental portal was created in the sinus tarsi and the scope was positioned in anterolateral portal no. 2 to fully expose the ATFL and dissect the extensor retinaculum. The ATFL was detached from any remaining attachments to the malleolar insertion with a cold scalpel. The anterior border of the lateral malleolus was scraped with a shaver. The ATFL was then tightened with the retinaculum with the help of two suture anchors (PushLock® Arthrex Naples FL USA).

### Anatomic ligament reconstruction

After debridement of the lateral groove, the gracilis tendon was harvested and prepared. In the previously described third portal, the insertion sites of the ATFL and CFL were prepared on the lateral malleolus with a shaver as well as that of the CFL on the calcaneum. The fibular and calcaneal tunnels were created through the sinus tarsi portal (transfibular tunnel and complete calcaneal tunnel) based on references described in a previous preliminary anatomical study [23]. The scope was then inserted through portal no. 1 and the shaver through anterolateral portal no. 2 to complete preparation of the talar insertion of the ATFL and the 20-mm blind-ending talar tunnel at the talar footprint [23]. The graft was then inserted into the fibular tunnel with an endobutton (TightRope® Arthrex Naples FL USA); then, the 2 bundles were attached in their respective tunnels with two suture anchors. (SwiveLock® Arthrex Naples FL). The

graft was tightened with the ankle in a neutral position with TightTrope®.

## Judgment criteria

The main judgment criterion was the appearance of the ATFL: (1) detached or thickened (Fig. 2); or (2) thin or absent (Fig. 3).

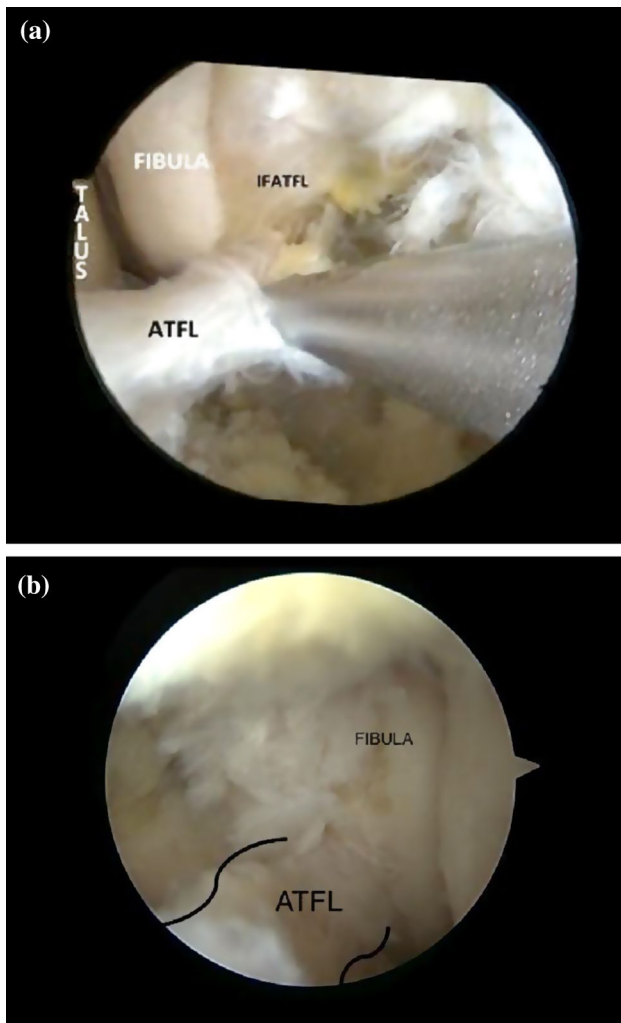
## Statistical analyses

Statistical analyses were performed with STATA/IC V.10 software. Parameters for the diagnostic accuracy of preoperative MRI were calculated in relation to arthroscopy: sensitivity (Se), specificity (Sp), positive (PPV) and negative predictive values (NPV) and the percentage of correctly classified patients. The intra- and interobserver reproducibility of preoperative MRI results of ATFL were evaluated using the kappa coefficient ( $k$ ). Kappa values were interpreted according to the Landis and Koch classification [15] in the following manner: no agreement if the kappa value was < 0.20, weak agreement if the kappa value was between 0.21 and 0.40, moderate agreement between 0.41 and 0.60, substantial agreement between 0.61 and 0.80, and nearly perfect agreement between 0.81 and 1.0. The level of significance of the kappa value was tested by the  $z$  test. The test was considered to be significant if  $z > 1.96$ .

## Results

### Study population (Fig. 4)

Between May 2013 and March 2016, 22 patients were included in the study, 15 men and 7 women between 15 and 53 years old, mean age  $30.3 \pm 9.5$ . The mean body mass index was



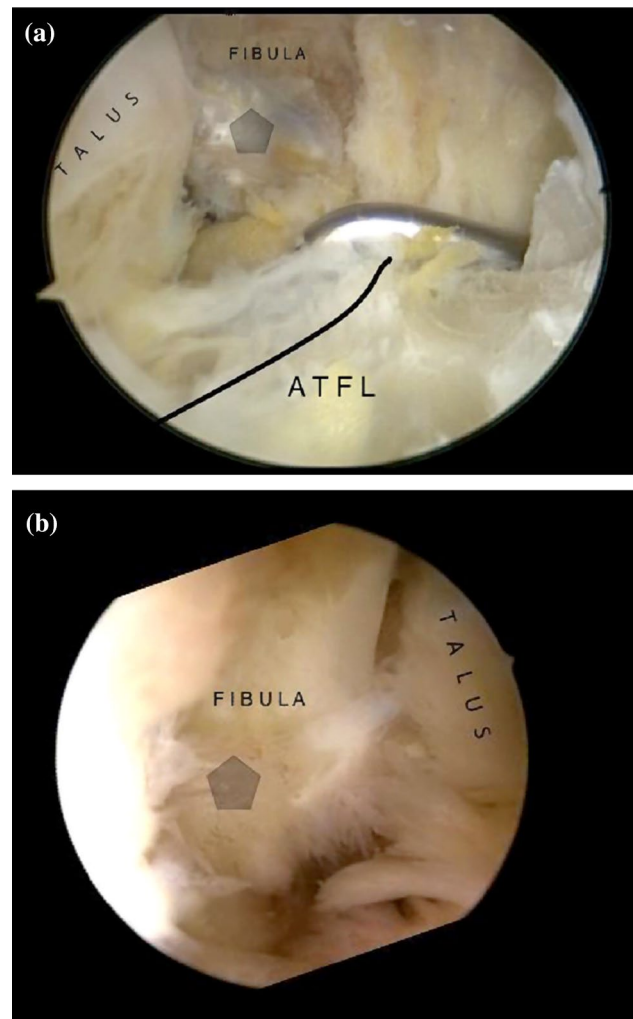
**Fig. 2** Examples of ATFL that could be repaired by a modified Broström procedure: **a** avulsion at the attachment of the fibula, **b** another example of reparable ligament with residual ligamentous tissue on footprint

$22.9 \pm 3.63 \text{ kg/m}^2$ . The delay between preoperative MRI and arthroscopy was 23–159 days with a median 65 days and a mean  $83 \pm 45.7$  days.

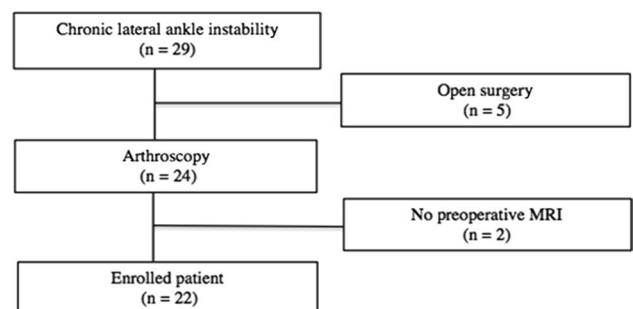
### Reliability of preoperative MRI of the ATFL

The intraobserver reproducibility was substantial and significant with an agreement of 77.3 and 81.8% (Table 1).

The interobserver reproducibility was moderate to nearly perfect and significant with agreement of 68.2–90.9% (Table 2).



**Fig. 3** Examples of irreparable ATFL with indication for ligament reconstruction: **a** disrupted ATFL with thin ligament and fatty infiltration, **b** lateral gutter of the ankle with undetectable ATFL (Diamond shows naked footprint)



**Fig. 4** Inclusion diagram

**Table 1** Intra-observer reproducibility of the preoperative evaluation of the ATFL on MRI

	Evaluation 1	Evaluation 2	Kappa	SE <sup>b</sup>	z	Agreement
Observer 1	<sup>a</sup> 1: 3 (13.6%)	1: 3 (13.6%)	0.75 (substantial)	0.13	5.8	81.8%
	2: 5 (22.7%)	2: 5 (22.7%)				
	3: 8 (36.4%)	3: 8 (36.4%)				
	4: 6 (27.3%)	4: 6 (27.3%)				
Observer 2	1: 1 (4.5%)	1: 3 (13.6%)	0.68 (substantial)	0.13	5.4	77.3%
	2: 6 (27.3%)	2: 4 (18.2%)				
	3: 11 (50%)	3: 8 (36.4%)				
	4: 4 (18.2%)	4: 7 (31.8%)				

<sup>a</sup>1 = ATFL absent/2 = ATFL thin/3 = ATFL normal/4 = ATFL thick

<sup>b</sup>Standard error of kappa score values

**Table 2** Intra-observer reproducibility of the preoperative evaluation of the ATFL on MRI

Observer 2	Observer 1	
	Evaluation 1	Evaluation 2
Evaluation 1	<i>K</i> = 0.55 (moderate)	<i>K</i> = 0.87 (almost perfect)
	SE = 0.13	SE = 0.13
	Z = 4.2	Z = 6.8
	Agreement : 68.2%	Agreement: 90.9%
Evaluation 2	<i>K</i> = 0.67 (substantial)	<i>K</i> = 0.75 (substantial)
	SE = 0.13	SE = 0.13
	Z = 5.3	Z = 5.8
	Agreement: 77.3%	Agreement: 81.8%

**Table 3** Validity of the preoperative evaluation of the ATFL on MRI compared to peri-arthroscopic evaluation

Arthroscopic assessment	Observer 1	Observer 2
	<i>K</i> = 0.80 (substantial)	<i>K</i> = 0.70 (substantial)
	SE = 0.21	SE = 0.21
	Z = 3.8	Z = 3.3

### Validity of preoperative MRI compared to arthroscopy

MRI showed that the ATFL was absent in 3 patients (14%), thin in 5 (23%), normal but detached on the fibular or talar side in 8 (36%) and thick in 6 (27%). The ATFL was absent or thin in 8 patients, and normally thick and detached or thick in 14 patients.

Arthroscopic exploration identified an injured ATFL in all patients: the quality of the ATFL was poor or the ATFL was absent in 8/22 cases (36.4%) indicating graft ligament reconstruction, and thickened or detached in 14 cases (63.6%), but with a good enough quality to allow a modified Broström repair technique.

Agreement between MRI and arthroscopy was substantial and significant (Table 3).

### Parameters for the diagnostic accuracy of preoperative MRI

The sensitivity and specificity of preoperative MRI for observer 1 was 87.5% and 92.9%, respectively. The positive predictive value (PPV) and the negative predictive value (NPV) of MRI was 87.5 and 92.9%, respectively, with a correlation of 90.9% between lesions identified on MRI and on arthroscopy.

The sensitivity and specificity for observer 2 was 85.7 and 86.7%, respectively, the PPV was 75%, the NPV 92.9%, and the correlation between MRI and arthroscopy was 86.4%.

### Discussion

In this study, preoperative evaluation of the ATFL by MRI was reliable and was strongly correlated to the peri-arthroscopic assessment and made it possible to predict the perioperative surgical technique, repair or reconstruction in 90.9% of patients undergoing surgery for chronic ankle instability. Preoperative knowledge of the surgical procedure is useful for both the surgeon and the patient.

A normal ligament is composed of 90% type 1 collagen, which is the reason for its mechanical qualities and resistance [6]. Any loss of type 1 collagen changes the mechanical qualities of and weakens the ligament. Yasui et Takao [29] showed that there was a good correlation between arthroscopic evaluation of an irregular remaining ATFL and its histological appearance.

Thus, a perioperative ATFL that is irregular with scar tissue was correlated with lower amounts of type 1 collagen. These results confirm the value of performing exploratory arthroscopy to obtain a precise assessment of the ligament and choose between surgical ligament repair and reconstruction. However, this choice is mainly based

on the surgeon's experience and there are no precise or reliable preoperative imaging criteria to decide upon the type of intervention.

Although MRI is frequently used and has been validated for the diagnosis of acute ankle sprains [14, 19, 21], its use in the evaluation of chronic ankle instability is controversial [3, 17]. The ATFL may present with numerous abnormal features on MRI. It can be absent, thin, irregular, normally thick but irregular or wavy, thickened or with a increased interligamentous signal intensity [3]. Several studies have already evaluated the validity of MRI compared to arthroscopy and shown that it is a good diagnostic tool for chronic ATFL lesions [4, 5, 12, 17, 19, 21, 22]. However, the results are highly variable with a sensitivity for MRI of 87–92%, a specificity of 60–100%, for an estimated accuracy of 71–93% for the diagnosis of chronic ATFL injuries depending on the study [21, 22].

In our study, there was a strong correlation between MRI and arthroscopic results, with, depending on the reader, a sensitivity, specificity, PPV and NPV of 85.7 and 87.5%, 86.7 and 92.9%, 75 and 87.5%, and 92.9%, respectively, as well as 86.4 and 90.9% of patients who were well classified. To our knowledge, this is the first study to compare the type of ATFL lesions identified on MRI with the arthroscopic features of the ATFL, while basing the choice of surgical technique on the quality of the remaining ligament. A similar study comparing preoperative MRI ATFL features and perioperative macroscopic findings from open surgery confirmed the value of preoperative MRI associated with stress radiography images for preoperative planning [10].

In our study, there was agreement between assessment of the ATFL on MRI and arthroscopic findings in 20/22 cases: 7 patients had an absent or thin ATFL requiring graft ligament reconstruction and 13 patients had a detached or thickened ATFL allowing repair by a modified Broström procedure. The surgical stabilization procedure was not adapted to the injury identified on MRI in two patients: in one case repair was performed on an ATFL that was absent or thin on MRI and in the other reconstruction was performed on an ATFL that appeared normal on MRI but was found to be of poor quality when palpated. These cases of disagreement can be explained by anatomical variations in the ATFL whose mean thickness is  $2.19 \pm 0.6$  mm and difficulty analyzing the talofibular groove in the presence of fibrosis, capsular thickening and scar tissue [17, 24].

The intraobserver reproducibility was substantial for both readers, and the interobserver reproducibility was from moderate to nearly perfect. Assessment of the anterolateral groove has been shown to be difficult in patients with chronic lateral ankle instability [5]. The joint capsule is joined to the anterior talofibular ligament, and numerous changes may be observed without abnormal features on MRI (fibrosis, synovitis). Moreover, certain authors have reported

that the anterior talofibular ligament can easily be confused with the adjacent anterior tibiofibular ligament on MRI [4].

Assessment of the ATFL on MRI in patients with chronic ankle instability has been extensively debated in the literature. More precise imaging techniques and improvements in knowledge and analysis in this field make it possible for the present study to confirm the tendency of the findings in the past few years. Thus, our study confirms that MRI is an accurate and reliable tool for assessment of the ATFL and for preoperative planning in patients undergoing surgical treatment of chronic ankle instability.

Dynamic (stress) MRI may be a future technique to obtain qualitative preoperative evaluation of the ATFL and more precisely determine the mechanical quality of the remaining ligament [22, 24].

Our study has several limitations. The first was the small number of included patients. A prospective study including a larger number of patients must be conducted to confirm our results. The second was the fact that all MRI were not performed in the same center using the same protocol. Although most MRI were performed with the ankle in the neutral position (90°, without pronation or supination), variations in ankle position could modify ligament tension and thus introduce a bias to our study. The third limitation was that the surgeon who performed the arthroscopic ligament assessment was experienced and specialized in ankle surgery. This allowed us to offer a reliable reference examination that was used to provide a robust and usable MRI classification even by less experienced teams.

## Conclusion

Preoperative MRI is a reliable and valid decision-making tool to evaluate the ATFL and choose the technique for surgical stabilization of patients with chronic lateral ankle instability. In this study, MRI correctly determined the perioperative choice of the surgical technique, ligament repair or anatomical reconstruction, in 90.9% of operated patients.

## Compliance with ethical standards

**Conflict of interest** T Bauer is consultant for Arthrex. P.Hardy is consultant for Arthrex and Zimmer. The other authors (A Morvan, S Klouche, A Thès) declare that they have no conflict of interest concerning this article.

**IRB/Ethical Committee** According to the past Huriet law on biomedical research and to the current regulation that went into effect in August 2006 (law no. 2004-806), such studies do not require prior submission or approval to/from an IRB, and they do not require written consent. The database was declared at the National Commission for Data Protection (*Commission Nationale de l'Informatique et des Libertés*, CNIL, N°470235).

**Informed consent** Informed consent was obtained from all individual participants included in the study.

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