Fig. 1 Ultrasound examination of the patellar mobility in the superior–inferior direction during isometric knee extension exercise. a The participants were evaluated in a supine position with the knee immobilized with a semi-flexed brace. b An ultrasound probe was fitted onto the skin overlying the patellar tendon in the sagittal plane using water bag kit. c The probe was positioned so that the caudal pole of the patella and the tibia tuberosity were visible within the viewing field. d, e Ultrasound images of the patella, patellar tendon, and tibial tuberosity at rest and during isometric knee extension contraction. The patellar mobility in the superior–inferior direction was measured as the change in distance between manually marked points of the deep insertion to the caudal pole of the patella and tibia tuberosity

volunteered for the study. Mean (±SD) age, height, and weight were 31.2 ± 6.9 years, 175 ± 3.7 cm, and 67.8 ± 8.6 kg, respectively. Ultrasound examinations were performed by an orthopedic surgeon and an ultrasonographer experienced in musculoskeletal ultrasound measurements.

Procedure

Participants performed three trials of maximal knee extension contractions in the supine position with the knee immobilized by a semi-flexed knee brace (Fig. 1a). An 8.0 MHz, 58-mm ultrasound probe (Aplio[TM] 300, Toshiba, Tokyo, Japan) was fitted onto the skin overlying the patellar tendon in the sagittal plane using a water bag kit (UAWB-022A, Toshiba). The probe was positioned so that the inferior pole of the patella and the tibial tuberosity were within the viewing field during isometric knee extension contraction (Fig. 1b–e).

All trials were performed on two different days and analyzed independently by two observers. Using recorded ultrasound images, the observer manually marked the points of the inferior pole of the patella and the tibial tuberosity frame by frame. The patellar mobility in the superior–inferior direction was defined as the change in distance between the two points during isometric knee extension contraction.

Statistical analysis

Continuous variables are expressed as mean ± SD. Both intra-observer and inter-observer reliability were assessed using intra-class correlation coefficients (ICC). Bland–Altman analysis was used to assess agreement between measurements. All statistical analyses were performed using SPSS (SPSS Inc., Chicago, IL, USA).

Results

The intra-observer reproducibility for patellar mobility was excellent, with an ICC (1, 3) of 0.97. In Bland–Altman plots, the mean difference between paired measurements by two observers was 0.03 mm. The corresponding 95 % limits of agreement were −0.55 to 0.61 mm (Table 1).

The inter-observer reproducibility for patellar mobility was also excellent, with an ICC (2, 3) of 0.93. In Bland–Altman plots, the mean difference between paired measurements by two observers was 0.02 mm. The corresponding 95 % limits of agreement were −0.82 to 0.85 mm (Table 1).

Discussion

The principal findings of the present study were that patellar mobility in the superior–inferior direction during

Table 1 .

Intra-observer	Mean ± SD		ICC (95 % CI)	Mean difference	Limits of agreement
	Day 1	Day 2			
Patella–tuberosity distance (mm)					
Rest	44.2 ± 5.3	44.4 ± 5.2	0.99 (0.96–1.00)	−0.22	−1.88 to 1.43
Contraction	47.3 ± 5.4	47.5 ± 4.7	0.98 (0.94–1.00)	−0.2	−2.1 to 1.8
Patellar mobility (mm)	3.1 ± 1.2	3.1 ± 1.2	0.97 (0.91–0.99)	0.03	−0.55 to 0.61

Interobserver	Mean ± SD		ICC (95 % CI)	Mean difference	Limits of agreement
	Observer 1	Observer 2			
Patella–tuberosity distance (mm)					
Rest	44.2 ± 5.3	44.0 ± 5.2	0.98 (0.93–0.99)	0.2	−2.2 to 2.5
Contraction	47.3 ± 5.4	47.1 ± 5.4	0.98 (0.94–0.99)	0.2	−2.0 to 2.3
Patellar mobility (mm)	3.1 ± 1.2	3.1 ± 0.9	0.93 (0.77–0.98)	0.02	−0.82 to 0.85

an isometric knee extension exercise could be reproducibly measured using ultrasound. ICC values were excellent for both intra-observer and inter-observer reliability at 0.97 and 0.93, respectively. In 95 % of measurements, the same observer measured within −0.55 to 0.61 mm, while different observers measured within −0.82 to 0.85 mm.

Ultrasound evaluation of the patellar tendon has been used extensively in recent years. There are several publications describing the ultrasound appearance of patellar tendinopathy and ultrasound measurements of mechanical properties of the patellar tendon [6, 7]. However, to our knowledge, this is the first report showing the utility of ultrasound in evaluating patellar mobility during a knee rehabilitation exercise.

Measurement of patellar tendon length with ultrasound using adjustable surface markers and calipers is highly accurate and has good inter-observer reliability [8]. Hansen et al. [6] performed patellar tendon measurements, keeping 90° of flexion with a custom made rigid cast to position an ultrasound probe, and showed high accuracy and reproducibility using measurements from two trials after discarding trials with the smallest and largest measurements. In a recent report, Schulze et al. [9] concluded that 5–6 trials are required for reliably measuring tendon elongation. In the present study, simple tools available in the clinical setting were used to perform the measurements, and an average of three trials showed sufficient reliability for clinical application.

Although abnormal patellar mobility potentially contributes to several knee disorders, such as anterior knee pain, patellofemoral pain, and arthrofibrosis, there is no strong evidence to support its importance, partially due to the lack of a standard measurement method [1, 3, 4, 10]. Considering the patient tolerability, low cost, and lower time commitment of our simple method, clinicians can easily evaluate patellar mobility before and after treatment. In addition to the conventional assessment of quadriceps

muscle strength, this method will help establish appropriate and effective treatment strategies [1]. Furthermore, objective evaluation of patellar mobility in the clinical context has the potential to provide clues to underlying causes of knee disorders as well as monitor treatment effects.

Limitations of the current study include the small sample size and the fact that the general condition of participants was not assessed. Although ICCs of intra-observer and inter-observer reproducibility were high, further study is required to clarify the utility of the present method for a large cohort. Another limitation is that we did not include measures of quadriceps muscle force. In the future, it would also be interesting to test the relationship between muscle force and patellar mobility.

In conclusion, patellar mobility in the superior–inferior direction during an isometric knee extension exercise can be reproducibly measured using ultrasound. Clinical application should provide useful information for treatment evaluation and planning in rehabilitation therapy.

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ORIGINAL ARTICLE

Patellofemoral chondral status after medial patellofemoral ligament reconstruction using second-look arthroscopy in patients with recurrent patellar dislocation

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Abstract

Background Most patients with recurrent patellar dislocation show cartilage damage in the patellofemoral joint. Medial patellofemoral ligament reconstruction has become one of the most important surgical techniques for treating recurrent patellar dislocation. However, patellofemoral chondral status after this reconstruction has not been elucidated. The purpose of this study was to investigate the effects of medial patellofemoral ligament reconstruction on articular cartilage in the patellofemoral joint by comparing the arthroscopic chondral status at the time of reconstruction with that at second-look arthroscopy.

Methods Participants in the present study comprised 31 patients (22 females, 9 males; 32 knees) who underwent second-look arthroscopy at a median of 12 months (range 6–40 months) after dual tunnel medial patellofemoral ligament reconstruction using a double-looped autologous semitendinosus tendon graft. Median age at the time of initial surgery was 20 years (range 13–43 years). The patellofemoral joint was divided into six portions, comprising the medial facet of the patella, central ridge, lateral facet of the patella, anterior medial femoral condyle, femoral groove, and anterior lateral femoral condyle. Chondral status in each portion according to the International Cartilage Repair Society classification was retrospectively evaluated at the time of initial surgery and second-look arthroscopy.

Results Before medial patellofemoral ligament reconstruction, chondral lesions were observed in the patellofemoral joint in 31 knees (97 %). At the central ridge of the patella, chondral damage was observed in 22 knees (69 %) at initial surgery and damaged cartilages showed recovery in 6 knees. No significant difference in the alteration of chondral status was seen for the medial facet, lateral facet of the patella, anterior medial femoral condyle, femoral groove, and anterior lateral femoral condyle.

Conclusions According to short-term results, the patellofemoral chondral status after medial patellofemoral ligament reconstruction was not altered at second-look arthroscopy in most part of patellofemoral joint. At the

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central ridge of the patella, significant improvement of the International Cartilage Repair Society grading was observed.

Introduction

The importance of the medial patellofemoral ligament (MPFL) as the primary soft-tissue restraint to lateral displacement of the patella has been corroborated by several studies [1–3], and MPFL reconstruction has become one of the most important surgical techniques for treating recurrent patellar dislocation [4, 5]. Many operative techniques to reconstruct the MPFL have been described, and good mid-term clinical results with up to 97 % patient satisfaction and over 10 years of follow-up have been reported [6].

Most patients with recurrent lateral patellar dislocation show cartilage damage in the patellofemoral joint caused by excessive lateral load, and continuation of patellar dislocation exacerbates patellar cartilage lesions [7]. Several in vitro studies have shown good effects of MPFL reconstruction on patellofemoral kinematics and contact pressure [8, 9]. Articular cartilage lacks a blood supply and is thus regarded as having poor healing potential [10]. However, one report supports the notion that cartilage lesions caused by abnormal knee kinematics may be healed with the restoration of normal knee kinematics [11]. This fact may be relevant to MPFL reconstruction.

On the other hand, over-tensioning of the graft and non-anatomical surgery reportedly have adverse effects on patellofemoral articular cartilage. Moreover, the usage of a much stronger tendon than the native MPFL, such as the semitendinosus tendon or gracilis tendon, could also adversely affect the patellofemoral joint [12]. MPFL reconstruction thus still carries a risk for the development of osteoarthritis, and clarification is needed to show whether the restoration of normal patellar tracking and preventing further dislocation by MPFL reconstruction can change the natural course of cartilage damage in patients with recurrent patellar dislocation and avert further development of osteoarthritis.

One study has investigated the arthroscopic chondral status after MPFL reconstruction [13]. However, the detailed location-specific response of damaged articular cartilage after MPFL reconstruction has not been described. The purpose of this study was to compare arthroscopic chondral status at MPFL reconstruction with that at second-look arthroscopy and to investigate the effects of MPFL reconstruction on the articular surface of the patellofemoral joint. Our hypothesis was that anatomical MPFL reconstruction would not aggravate the patellofemoral joint surface.

Materials and methods

Patients

Between 2000 and 2009, a total of 81 patients underwent MPFL reconstruction using double-looped semitendinosus tendon at our hospital. All patients had patellar dislocation twice or more and had been diagnosed with recurrent patellar dislocation on physical examinations, showing a positive apprehension sign in all cases. Among all 81 patients, 8 with a history of prior knee surgery (osteochondral fracture fixation, 3 patients; medial tubercle transfer, 2 patients; lateral retinaculum release, 2 patients; medial reefing, 1 patient) and 2 (2.5 %) who had suffered postoperative patellar fractures were excluded from the investigation. One patient (1.2 %) with re-dislocation during the follow-up period was also excluded from the study. All patients included in this study underwent only MPFL reconstruction using double-looped semitendinosus tendon without any other additional surgical procedure or any intervention involving articular cartilage. Prior to MPFL reconstruction, informed consent for second-look arthroscopy 1-year after the initial surgery was obtained from all patients. Participants in the present study comprised 31 patients (22 females, 9 males; 32 knees) who underwent second-look arthroscopy at a median of 12 months postoperatively (range 6–40 months) with 2 or more years of follow-up. Median age at the time of MPFL reconstruction was 20 years (range 13–43 years). Median Tegner activity score was 4 (range 3–9) (Table 1). According to Wiberg's classification, the shape of the patellae of 12 patients was classified as type II and that of 20 patients was as type III. Based on trochlear dysplasia classification according to Dejour [14], 7 knees had type A trochlear dysplasia, 2 had type B, 8 had type C, and 12 had type D. The study was approved by the local ethics committee and was conducted according to the principles of the Declaration of Helsinki. The patients were informed that data from the case would be submitted for publication and gave their consent.

Surgical technique

All reconstructions were performed using a modified "dual tunnel medial patellofemoral ligament reconstruction" technique, as reported by Toritsuka et al. [15]. First, chondral status and patellar tracking were carefully evaluated by arthroscopy. A semitendinosus autograft was then harvested. The distal end of the tendon was used and doubled over. A small 1-cm incision was made on the lateral side of the patella, and a skin incision approximately 5 cm in length was made from the medial patellar edge to the medial femoral epicondyle. Two patellar guidewires

Table 1 Demographic data and arthroscopic findings

Patient	Sex	Age	Tegner activity scale	Wiberg classification	Dejour's trochlear dysplasia classification	ICRS classification											
						Before MPFL reconstruction						Second-look arthroscopy					
						MP	CR	LP	MF	FG	LF	MP	CR	LP	MF	FG	LF
1	M	23	4	3	C	0	4	4	0	0	0	0	2	2	0	0	0
2	F	31	3	3	D	0	2	0	0	4	0	0	2	0	0	4	0
3	F	15	4	2	C	4	2	2	0	0	1	4	2	2	0	0	0
4	F	16	9	3	D	3	4	0	0	0	0	3	3	0	0	1	0
5	M	20	8	3	D	0	4	0	0	0	2	0	4	0	0	2	0
6	F	14	4	3	D	0	3	0	0	2	0	0	3	0	0	2	0
7	F	33	3	3	C	0	4	0	0	0	0	0	4	0	0	0	0
8	M	27	6	3	A	2	0	0	0	0	0	3	0	0	0	1	0
9	F	20	3	3	D	0	4	0	0	1	0	0	4	0	0	1	0
10	F	18	4	3	B	0	1	0	0	0	1	0	1	0	0	0	0
11	M	18	9	2	D	0	4	0	0	0	2	0	4	0	0	0	2
12	M	28	4	3	D	4	0	0	0	0	1	4	0	0	0	0	0
13	M	20	7	3	B	4	2	0	0	2	0	4	2	0	0	2	0
14	M	23	6	2	A	3	0	0	0	0	0	3	0	0	1	0	0
15	M	18	9	2	C	0	3	0	0	0	0	0	3	0	0	0	0
16	F	16	4	3	C	0	4	0	0	0	0	0	2	0	0	0	0
17	F	28	3	2	C	0	2	0	1	0	0	0	2	0	0	0	0
18	F	21	3	3	D	3	0	0	0	0	2	3	0	0	0	0	2
19	F	18	3	2	A	0	4	0	0	0	0	0	3	0	0	0	0
20	F	14	7	3	D	0	1	0	0	0	0	0	1	0	0	1	0
21	F	39	7	2	C	0	2	0	0	0	2	0	2	0	0	0	1
22	F	20	4	3	A	0	2	0	0	0	3	0	1	0	0	0	0
23	F	13	7	2	A	0	1	0	0	0	0	0	1	0	0	0	0
24	F	17	3	3	D	2	0	0	0	0	0	2	0	0	0	0	0
25	F	22	3	3	N	0	0	1	0	0	0	0	0	1	0	0	0
26	F	13	3	3	N	0	4	0	0	0	0	0	2	0	0	0	0
27	F	39	3	2	D	1	0	0	0	0	0	2	0	0	0	0	0
28	M	14	7	3	N	3	0	0	0	0	0	3	0	0	0	0	0
29	F	43	6	3	A	4	0	0	2	0	0	1	0	0	1	0	0
30	F	23	3	2	C	0	2	0	0	0	0	0	2	0	0	0	0
31	F	35	3	2	A	0	2	0	0	0	0	0	2	0	0	1	0
32	M	17	3	2	D	2	0	0	0	0	0	2	0	0	0	1	0

MP medial facet of the patella, *CR* central ridge of the patella, *LP* lateral facet of the patella, *MF* anterior medial femoral condyle, *FG* femoral groove, *LF* anterior lateral femoral condyle, *N* normal

were transversely inserted, one from the proximal one third of the medial edge of the patella and the other from the center of the patella. Patellar guidewires were over-drilled using a 4.5-mm cannulated reamer to create sockets with a depth of 15 mm. Another guidewire was inserted from the superoposterior portion of the medial femoral epicondyle toward the proximal cortex of the lateral femoral condyle. The guidewire was overdrilled with an ENDOBUTTON® drill (Smith and Nephew Endoscopy, Andover, MA), and a 5–6 mm socket was created at the anatomical femoral insertion of the MPFL. The center of the graft was pulled into the femoral socket and fixed using an ENDOBUTTON®. The two free ends of the graft were pulled into the bone sockets of the patella and fixed using an ENDO-BUTTON® on the lateral side of the patella at 45° of knee flexion. At this time, care was taken not to place too much tension on the graft. After fixation of both sites, negative manual lateral dislocation of the patella was confirmed.

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Postoperative Management

The knee was immobilized with a brace at 45° of knee flexion. Upon removal of the brace at 2 weeks after MPFL reconstruction, passive and active-assisted range of motion exercises for the knee were started. Weight-bearing was gradually increased to full at 4 weeks postoperatively. Running was allowed at 3 months, followed by a return to previous sporting activity at 6 months [13].

Evaluations

Chondral status of the patellofemoral joint according to the International Cartilage Repair Society (ICRS) classification [16] was retrospectively evaluated using photographs taken both at the time of MPFL reconstruction and at the second-look arthroscopy through lateral suprapatellar and antero-lateral parapatellar portals. The photographs taken both at the initial surgery and at the second second-look arthros-copy were evaluated by the senior author and the corresponding author, respectively. The patellofemoral joint was divided into six portions, comprising the medial facet, central ridge and lateral facet of the patella, and the anterior medial femoral condyle, femoral groove, and anterior lateral femoral condyle. Chondral status in each portion at the time of MPFL reconstruction was compared with that at second-look arthroscopy. Clinical data including the incidence of recurrent patellar subluxation or dislocation, lateral patellar mobility, lateral patellar apprehension sign, and Kujala score were evaluated. Pre- and postoperative radiographic values including the sulcus angle, lateral tilt angle, and congruence angle were also evaluated [13].

Statistical analysis

The data analyses were expressed as mean ± standard deviation (SD) of the mean. Statistical analyses were performed using Student's t test and the Wilcoxon rank-sum test. Values of $P < 0.05$ were defined as significant.

Results

All patients showed a normal range of motion at the time of second-look arthroscopy. As for passive patellar mobility, abnormal lateral patellar movement was identified in all cases preoperatively. At second-look arthroscopy, all patellae were firmly fixed within the femoral groove, and no abnormal lateral mobility was evident in any case. Mean Kujala score improved from 72 ± 8 to 94 ± 5 at 2-year follow-up. While 28 knees showed clear improvements in the apprehension sign, positive results were still evident in 4 knees. Mean sulcus angle was 147.8° ± 8.9°.

Table 2 Radiographic measurement

	Before MPFL reconstruction	Immediately after MPFL reconstruction	Second-look arthroscopy
Lateral tilt angle (°)	−6.1 ± 15.6	5.4 ± 9.3[a]	−2.6 ± 13.8[a,b]
Congruence angle (°)	17.4 ± 22.8	−11.3 ± 18.7[a]	7.8 ± 22.3[a,b]

Values are expressed as mean ± standard deviation

[a] $P < .05$ compared with before MPFL reconstruction

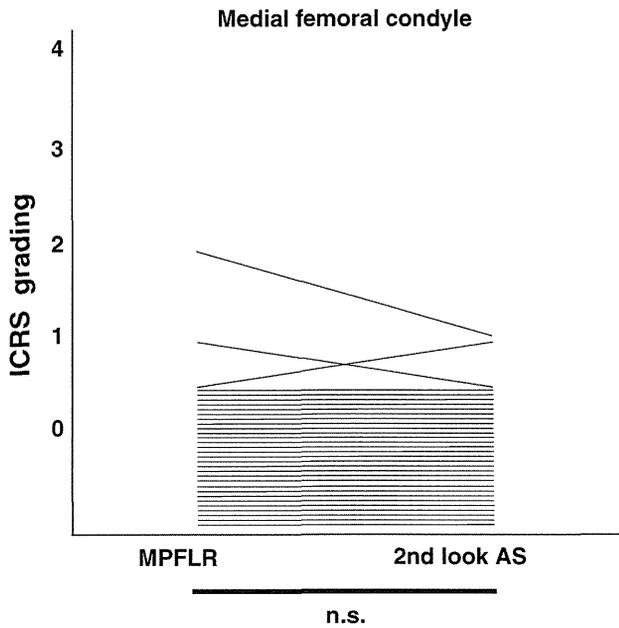[b] $P < .05$ compared with immediately after MPFL reconstruction
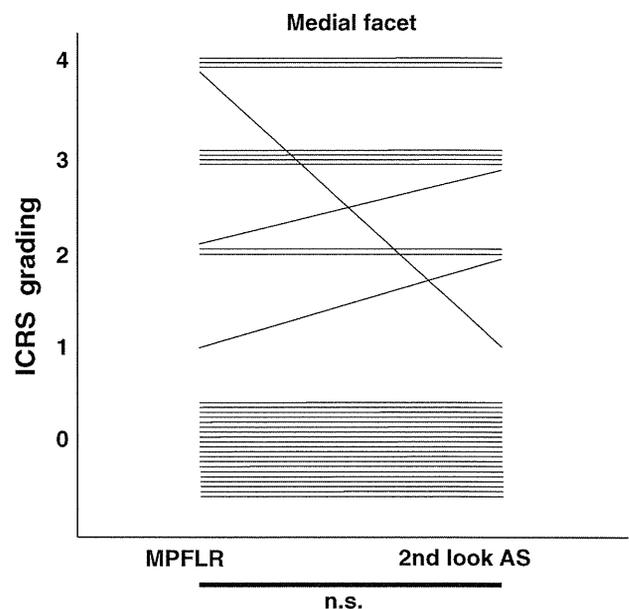
Fig. 1 Chondral status of the medial facet of the patella according to ICRS grading at MPFL reconstruction and at second-look arthroscopy
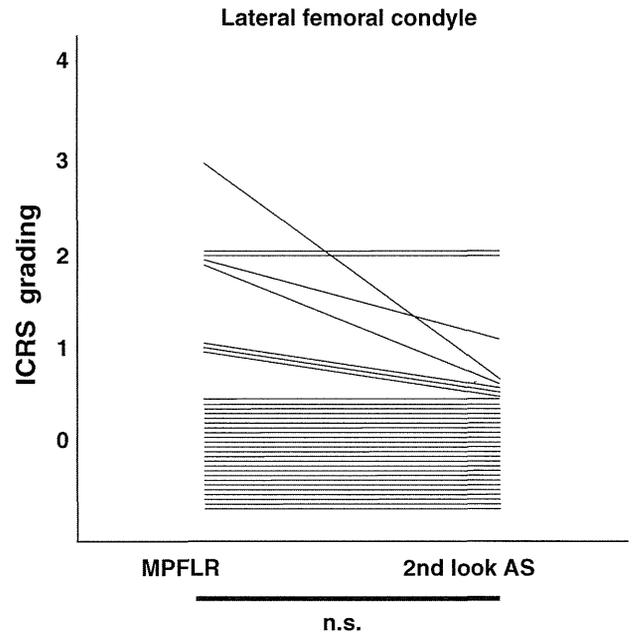
Preoperatively, mean lateral tilt angle and mean congruence angle were −6.1° ± 15.6° and 17.4° ± 22.8°, respectively. Immediately after MPFL reconstruction, these indices had improved. At second-look arthroscopy, these indices had returned toward preoperative values to some extent (Table 2). However, significant improvement was still seen at second-look arthroscopy.

At the time of MPFL reconstruction, chondral lesions were observed in the patellofemoral joint in 31 cases (97 %). Chondral damage at the medial facet of the patella was observed in 12 knees at MPFL reconstruction. No change of ICRS grading was observed in nine knees. One knee improved from grade 4 to 1. Two knees deteriorated (one knee from 2 to 3, one knee from 1 to 2). No significant difference in alteration of chondral status was seen for this location (Fig. 1). At the central ridge of the patella, chondral damage was observed in 22 knees at initial surgery. Of these, six knees exhibited improvement of ICRS grading (two knees from 4 to 3, three knees from 4 to 2,
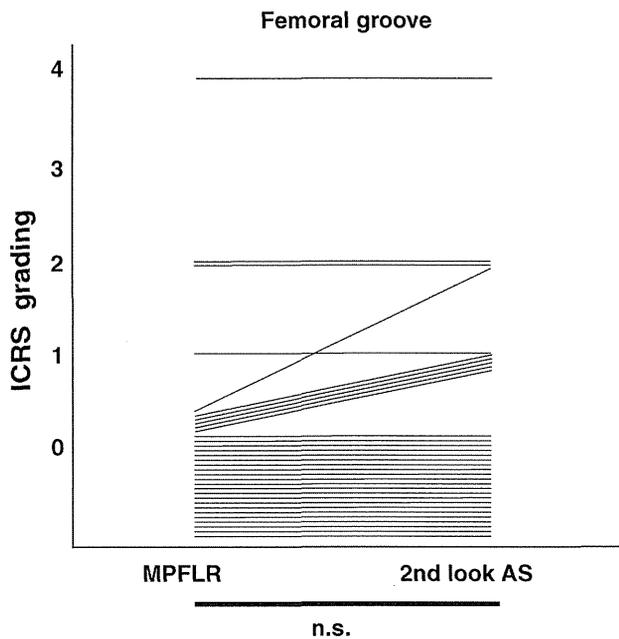
Fig. 2 Arthroscopic view of the chondral surface of the central ridge through the lateral suprapatellar portal at MPFL reconstruction (a) and at second-look arthroscopy (b). A gross articular cartilage fibrillation on the central ridge was seen, and the lesion was found to be deep to the subchondral bone on probing (a) A smooth fibrocartilaginous tissue covered the surface of the central ridge 6 months after MPFL reconstruction (b)

Fig. 3 Chondral status of the central ridge of the patella according to ICRS grading at MPFL reconstruction and at second-look arthroscopy

Fig. 4 Chondral status of the lateral facet of the patella according to ICRS grading at MPFL reconstruction and at second-look arthroscopy

and one knee from 2 to 1), and no cases showed deterioration of chondral lesions (Fig. 2). There was a significant difference between ICRS grade at MPFL reconstruction and at second-look arthroscopy (Fig. 3). No significant difference in Tegner score was found between improved patients and non-improved patients. Of the six knees with improvement in ICRS grading, 1 had normal trochlea, two had type A trochlear dysplasia, two had type C, and one had type D. In the lateral facet of the patella, only three knees exhibited cartilage damage at MPFL reconstruction. One knee improved from grade 4 to 2. There was no significant change in chondral status for this location (Fig. 4). The cartilaginous surface of the medial femoral condyle was not damaged in most patients (Fig. 5). Only four knees

exhibited cartilaginous damage (grade 1 in one knee, grade 2 in two knees, and grade 4 in one knee) in the femoral groove at MPFL reconstruction, while slight cartilaginous deterioration was observed in six knees (five knees from grade 0 to 1, one knee from grade 0 to 2) at second-look arthroscopy without a significant difference (Fig. 6). In the lateral femoral condyle, eight knees showed chondral damage, but six knees displayed improvement in ICRS grading at second-look arthroscopy (one knee from grade 3 to 0, one knee from grade 2 to 0, one knee from grade 2 to 1, and three knees from grade 1 to 0). There was no significant change in grading observed at the second-look arthroscopy (Fig. 7).

Medial femoral condyle

Fig. 5 Chondral status of the medial femoral condyle according to ICRS grading at MPFL reconstruction and at second-look arthroscopy

Lateral femoral condyle

Fig. 7 Chondral status of the lateral femoral condyle according to ICRS grading at MPFL reconstruction and at second-look arthroscopy

Femoral groove

Fig. 6 Chondral status of the femoral groove according to ICRS grading at MPFL reconstruction and at second-look arthroscopy

Discussion

The most important finding in the present study was that no significant deterioration of chondral status was observed following MPFL reconstruction in most of the patellofemoral joint. The present results suggest that anatomical MPFL reconstruction is unlikely to generate abnormal patellofemoral contact pressure.

Most patients with recurrent patellar dislocation have damaged cartilage in the patellofemoral joint, and continued patellar dislocations result in exacerbation of patellar cartilage lesions [7]. The purposes of treating recurrent patellar dislocation are not only to prevent further patellar dislocation, but also to prevent the progression of patellofemoral osteoarthritis. Long-term clinical results of the Elmslie-Trillat procedure were worse because of the onset or worsening of patellofemoral joint pain [17]. MPFL reconstruction has thus become one of the most important surgical techniques for treating recurrent patellar dislocation in place of the tibial tubercle transfer technique. Numerous reconstructive techniques have been reported to restore the medial restraint of the patella. Various tendon sources have been described including the hamstring [18], semitendinosus [19], gracilis [20], partial patellar tendon [21], quadriceps tendon [22], adductor tendon [23], and allografts or artificial tendons [6]. In addition, a variety of graft fixation techniques have been described [24]. Many researchers have reported quite low rates of re-dislocation after MPFL reconstruction [6, 13, 25], but whether MPFL reconstruction could prevent patellofemoral osteoarthritis is still unclear, and the optimal surgical treatment for chronic patellar instability remains controversial. Nomura et al. [6] reported no or only slight progression of osteoarthritis on radiographs 11.9 years after MPFL reconstruction, but no studies have investigated the chondral

surface of the patellofemoral joint after MPFL reconstruction by second-look arthroscopy.

Several papers have been reported for cartilage lesions of the patellofemoral joint in recurrent patellar dislocation [7, 26]. Nomura et al. [7] reported that the continuation of patellar dislocation made the patellar cartilage lesions worse. The mechanism for cartilage damage is thought to involve the shear stress produced as the patellar dislocates and reduces, and the medial facet and the central ridge of the patella engage the lateral femoral condyle. The main reason for the healing cartilage lesion on the central ridge after MPFL reconstruction seems to be avoidance of further dislocation by MPFL reconstruction. Before MPFL reconstruction, the patella was laterally shifted in all patients. After MPFL reconstruction, the patella was medialized to the center of the trochlear groove. However, such medialization of the patella by tightening of the medial structure might generate increased joint pressure at the patellofemoral joint, especially with high-graded trochlear dysplasia. In this series, three of six patients with improvement of chondral lesions had low-grade dysplasia, and the ratio was greater when compared to the entire cohort. The present results suggest that MPFL reconstruction could change the natural course of patellofemoral osteoarthritis for patients with recurrent patellar subluxation. However, fibrous cartilage tissue might cover the region of chondral damage in most cases. Because fibrous cartilage might be mechanically and biologically different from native hyaline cartilage tissue, longer follow-up with regard to the development of patellofemoral osteoarthritis is necessary.

On the other hand, slight deterioration in the femoral groove was observed in six knees without significance. This fact indicates that MPFL reconstruction might generate a slight increases in joint pressure at the patellofemoral joint, particularly in the femoral groove, by reducing the patella to the center on the femoral groove. Effects of MPFL reconstruction on patellofemoral contact pressure and kinematics have been investigated by several authors [3, 22, 27–29]. While Bicos et al. [3] reported that overload of the medial femoral trochlea was not noted with reconstruction of the MPFL, Elias et al. [27] reported that small errors in graft length and position could dramatically increase the force and pressure applied to the medial patellofemoral cartilage in vitro. Servien et al. [30] reported that only 65 % of femoral tunnels, the location of which had been identified by visual inspection during surgery, were located in a proper position after MPFL reconstruction. In the current case series, femoral tunnels were created using intraoperative anatomical landmarks alone, and non-anatomical placement of femoral tunnel might lead to cases with a deteriorated chondral surface in the femoral groove. Currently, all femoral drill positions are checked on intraoperative lateral radiography to achieve anatomical

placement of the femoral drill hole [28, 31]. Moreover, increased patellofemoral contact pressure could be avoided by applying low loads to the graft [29], checking graft isometricity [32], or adding lateral release, although further examination of this issue is needed before such recommendations can be applied clinically.

Several limitations in this study must be considered. First, not all patients who underwent MPFL reconstruction were examined in this series. Some potential for bias in patient selection may thus exist, and the 32 knees investigated in the present study might not have been representative of all 81 patients. Second, the stability and repeatability of the ICRS score have been reported as satisfactory, and internal consistency is adequate [33]. However, such a subjective evaluation method might influence the results, and objective evaluation methods such as magnetic resonance imaging should therefore be adopted. Third, a period of 1 year from initial surgery to second-look arthroscopy might be too short to detect the effects of MPFL reconstruction on the patellofemoral cartilage. Longer follow-up with regard to the development of patellofemoral osteoarthritis is necessary, and further examination is needed for the establishment of an optimal operation in order to prevent the onset of further osteoarthritis.

In summary, according to short-term results, patellofemoral chondral status after isolated anatomical medial patellofemoral ligament reconstruction was not altered at second-look arthroscopy in most part of patellofemoral joint. At the central ridge of the patella, significant improvement of ICRS grading was observed. Chondral injuries in general might not worsen after MPFL reconstruction.

Conflict of interest The authors report no conflict of interest.

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■ FOOT AND ANKLE

The use of MRI in pre-operative evaluation of anterior talofibular ligament in chronic ankle instability

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Objectives
To evaluate the applicability of MRI for the quantitative assessment of anterior talofibular ligaments (ATFLs) in symptomatic chronic ankle instability (CAI).

Methods
Between 1997 and 2010, 39 patients with symptomatic CAI underwent surgical treatment (22 male, 17 female, mean age 25.4 years (15 to 40)). In all patients, the maximum diameters of the ATFLs were measured on pre-operative T2-weighted MR images in planes parallel to the path of the ATFL. They were classified into three groups based on a previously published method with modifications: 'normal', diameter = 1.0 - 3.2 mm; 'thickened', diameter > 3.2 mm; 'thin or absent', diameter < 1.0 mm. Stress radiography was performed with the maximum manual force in inversion under general anaesthesia immediately prior to surgery. In surgery, ATFLs were macroscopically divided into two categories: 'thickened', an obvious thickened ligament and 'thin or absent'. The imaging results were compared with the macroscopic results that are considered to be of a gold standard.

Results
Agreement was reached when comparison was made between groups, based on MRI and macroscopic findings. ATFLs were abnormal in all 39 cases and classified as ten 'thickened' and 29 'thin or absent'. As to talar tilt stress radiography, a clear cut-off angle, which would allow discrimination between 'thickened' and 'thin or absent' patients, was not identified.

Conclusion
MRI is valuable as a pre-operative assessment tool that can provide the quantitative information of ATFLs in patients with CAI.

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Keywords: Chronic ankle instability (CAI), Anterior talofibular ligament (ATFL), MRI, Stress radiography

Article focus
- In cases where surgery is considered for symptomatic chronic ankle instability (CAI), it is imperative not only to detect injured lesions but also to document the extent of ligament tear and the quantity of residual ligamentous tissue.
- This study aimed to evaluate the applicability of MRI for the quantitative assessment of anterior talofibular ligaments (ATFLs) in symptomatic CAI.

Key messages
- On pre-operative MRI, ATFLs were abnormal in all 39 cases and classified as ten 'thickened' and 29 'thin or absent'.

- In all cases pre-operatively categorised as 'thickened', residual ligaments were thick enough to be advanced, as observed during surgery, and graft replacement was not required. In the remaining cases, we were unable to detect bulky or normal residual tissue, and reconstruction had to be performed. MRI is valuable as a pre-operative assessment tool that can provide the quantitative information of ATFLs in CAI patients.

Strengths and limitations
- This study is based on the experience of a single surgeon.

■ Stress radiography was performed under general anaesthesia immediately prior to surgery.

■ Small numbers were involved in this study.

Introduction

Acute lateral ankle ligament lesions are the most common injuries sustained in sports and recreational activities.[1,2] Although most of these injuries can be treated successfully with conservative treatment, the development of chronic ankle instability (CAI), characterised by the occurrence of repetitive ankle sprains and persistence of symptoms after the initial injury, is not uncommon.[3-5] Increased ligamentous laxity is one of the main causes of residual symptoms after ankle sprains, and failure of appropriate conservative management is an indication for surgical treatment.[6,7] The anterior talofibular ligament (ATFL) is the main lateral stabiliser of the ankle joint and is most commonly affected first, followed by the calcaneofibular ligament (CFL) and the posterior talofibular ligament (PTFL).[8,9] In cases where surgery is considered for symptomatic CAI, it is imperative not only to detect injured lesions but also to document the extent of ligament tear and the quantity of residual ligamentous tissue, as anatomic repair is recommended when the quality of the ruptured ligaments permits, and anatomic reconstruction should be performed when ligaments are attenuated.[10,11] Although various imaging techniques such as stress radiography and MRI have been used for diagnosis,[12-15] few studies have examined the sensitivities of evaluation methods in providing information about residual ligamentous tissue.[16]

In this study, we pre-operatively assessed injured ATFLs in symptomatic CAI patients by MRI and stress radiography under general anaesthesia. Using surgical findings as the gold standard, we evaluated the use of these two methods as pre-operative assessment tools. We hypothesised that pre-operative MRI can quantitatively evaluate injured ATFLs, and is useful in surgical planning.

Patients and Methods

Patient population. Between March 1997 and December 2010, 39 symptomatic CAI patients underwent surgical treatment at our hospital. Clinical criteria were the same as those described in previous reports.[3,4,7] Patients had either a history of repetitive ankle sprains or persistent ankle pain that occurred after an acute lateral ankle sprain. The indication for surgical treatment was failure in conservative management after appropriate rehabilitation. There were 22 men and 17 women with a mean age of 25.4 years (15 to 40). The mean time between initial injury and surgery was 5.3 years (4 months to 20 years). All patients were evaluated pre-operatively by MRI and stress radiography was performed under general anaesthesia.

MRI. MRI was performed with a Hitachi Medical Corporation 0.4-T unit (Hitachi Electronics, Tokyo, Japan). The foot was placed in a neutral position and images were taken of each ankle in planes parallel to the path of the ATFL. Axial images were obtained using the following parameters: 16 cm field of view; 256 × 256 matrix; and 3 mm slice thickness with a 0.5 mm intersection gap. T1-weighted spin echo images were generated with a repetition time (TR) of 500 ms and echo times (TE) of 20 ms (500/20), and T2-weighted fast spin echo images were generated with a TR of 3500 ms and TE of 117 ms (3500/117).

Pre-operative MRI evaluation. On T2-weighted images, maximum diameters of the ATFLs were measured and classified into three categories based on a previously published method[17] with modifications: 'normal', diameter = 1.0 to 3.2 mm; 'thickened', diameter > 3.2 mm; 'thin or absent', diameter < 1.0 mm (Fig. 1). Cases in which the continuity of the ATFL could not be confirmed were classified as 'absent'.

Stress radiography. Stress radiography was performed with the maximum manual force in inversion under general anaesthesia. Talar tilt was measured as the angle formed by opposing articular surfaces of the tibia and talus.[18]

Surgical findings. ATFLs were evaluated and classified into two categories during surgery: 'thickened', an obvious thickened ligament; 'thin or absent', a maximum diameter of < 1.0 mm or when the path of the ligamentous tissue from the anterior aspect of the distal fibula at the malleolar fossa level to the neck of the talus was undetectable (Fig. 2).

Reliability analysis. A total of five patients were selected randomly and two orthopaedic surgeons classified their ATFLs on MRI. During surgery, two other orthopaedic surgeons who were blinded to use of the MRI evaluated the ATFLs; two of these were classified as 'thickened' and three 'thin or absent' on MRI, which agreed with our categorisation based on surgical findings.

Statistical analysis. Descriptive data are reported as mean (SD) and range. We used conventional statistical tests to compare outcomes in the two groups ('thickened' and 'thin or absent'). The chi-squared test was used for dichotomous variables, and the Mann–Whitney U test for all ordinal variables. Two-sided p-values < 0.05 were considered statistically significant. Data were analysed using Microsoft Excel (Microsoft Corporation, Redmond, Washington). A logistic regression analysis was performed using SPSS (SPSS Inc., Chicago, Illinois), with p < 0.05 considered statistically significant.

Results

ATFLs in all patients were abnormal at surgery. 'Thickened' and 'thin or absent' ATFLs were observed in ten and 29 cases, respectively (Table I).

There were no gender- or age-related differences between the two groups. The time between initial injury and surgery was significantly different in the two groups (thickened, 2.3 years (SD 2.2); thin or absent, 6.4 years (SD 6.1), p = 0.006).

MRI diagnosis and surgical findings. ATFLs were abnormal on pre-operative MRI in all 39 cases. Injured
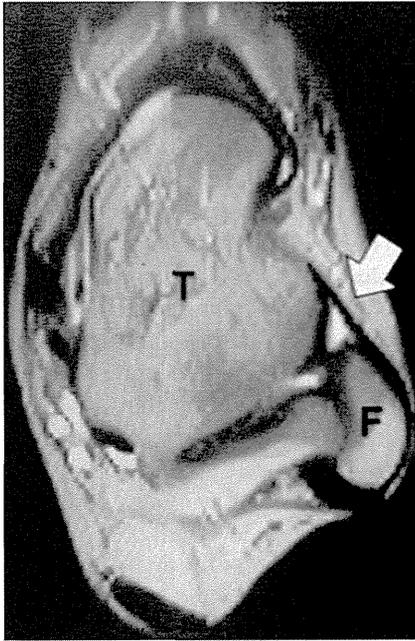
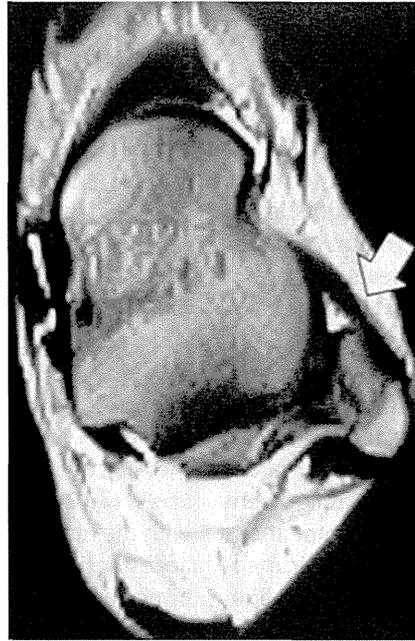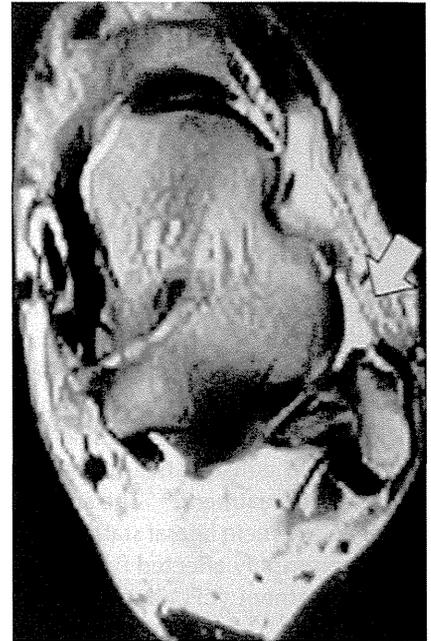<div align="center">Fig. 1a   Fig. 1b   Fig. 1c</div>

Axial T2-weighted images showing typical ATFL findings (white arrows). T and F denote tibia and fibula, respectively, the MRI evaluation was undertaken pre-operatively, and maximum diameters of the anterior talofibular ligaments (ATFLs) were measured.
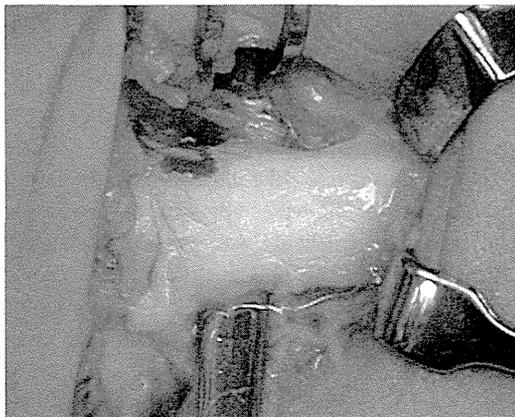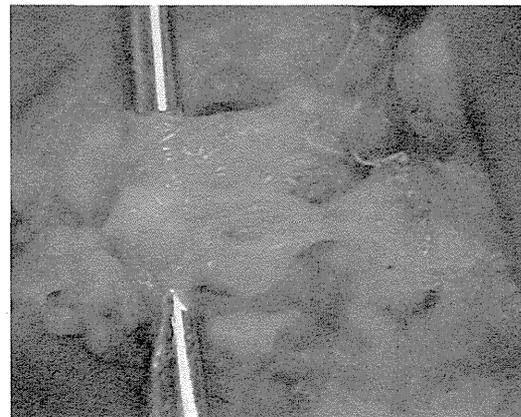

<div align="center">Fig. 2a   Fig. 2b</div>

Photographs showing the typical intra-operative appearance of injured anterior talofibular ligaments (ATFLs), either a) 'thickened' or b) 'thin or absent'.

ligaments were categorised as thickened (10), or thin or absent (29) (Table II).

Comparison with surgical findings revealed that all ten thickened ATFLs were correctly predicted by MRI.

Stress radiography and surgical findings. The mean talar tilt was 14.4 (SD 6.3°) (Table II, Fig 3). Comparison of the two groups categorised by surgical findings revealed a significant difference (thickened, 11.2 (SD 4.8°); thin or absent, 15.5 (SD 6.4°); p = 0.037). The angle of talar tilt did not have a significant effect on categorisation based on surgical findings using the logistic regression analysis (odds ratio: 0.872; p = 0.072), and a clear cut-off angle,

which would allow discrimination between 'thickened' and 'thin or absent' patients, was not identified (Fig. 3).

Discussion

CAI not only limits physical activity, but also leads to an increased risk of osteoarthritis, and patients with severe disability often need surgical treatment to restore mechanical stability.[5,19,20] Although various imaging methods, such as stress radiography, MRI, computed tomography, and ultrasonography, are available to facilitate precise diagnosis, the first two methods are most frequently used.[7,21]

Table I. Patient demographics categorised by surgical findings

Variable	Thickened*	Thin or absent*	p-value[†]
Total: women + men	10: 5 + 5	29: 17 + 12	
Age (years)			
Mean (SD)	21.4 (6.9)	25.9 (8.6)	NS
Min to max	15 to 34	16 to 40	
Time from initial injury to surgery (years)[‡]			
Mean (SD)	2.3 (2.2)	6.4 (6.1)	0.006
< 2 years, n	7	6	
2 years ≦ , n	3	22	

*'thickened' and 'thin or absent' denote the appearance of ATFLs during surgery
†p < 0.05 was considered statistically significant. NS, not significant
‡ In one case, the initial injury episode could not be confirmed

Table II. Comparison of pre-operative evaluations and surgical findings

	MRI		Stress radiography
Surgical findings	Thickened	Thin or absent	(Talar tilt)
Thickened	10	0	11.2 ± 4.8
Thin or absent	0	29	15.5 ± 6.4
All	10	29	14.4 ± 6.3
p-value			0.037*

* pairwise comparison revealed a significant difference between thickened and thin or absent categories
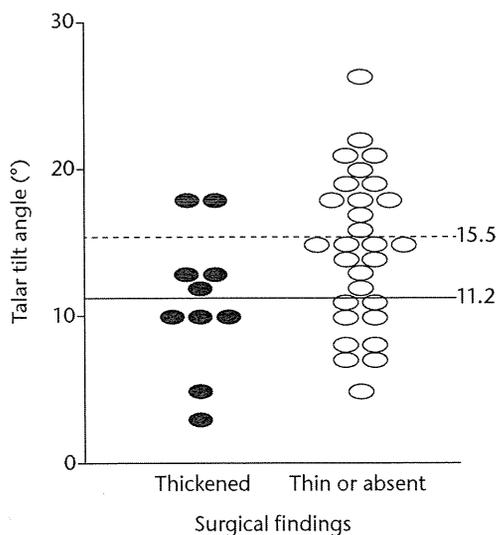
Fig. 3

Stress radiography data distribution for surgically-established anterior talofibular ligament (ATFL) categories. Angles of talar tilt were significantly different in the two surgically-established groups (thickened, 11.2 (SD 4.8°); thin or absent, 15.5 (SD 6.4°); p = 0.037). A clear cut-off angle was not identified.

The anterior drawer test and talar tilt stress radiographs are commonly used in the clinical setting.[18,22] However, these measurements correlate poorly with the degree of ligamentous disruption due to large individual variations.[15,17,23] Some patients have bilateral ankle sprains, which render comparison with the contralateral side unreliable. Furthermore, some investigators claim that radiographic stress tests cause pain and muscle spasms that restrict movement unless the joint is anaesthetised.[14,15,18] To overcome these problems, both stress radiographs in the present study were obtained under general anaesthesia in the operating room and a side-by-side comparison was not performed. The mean angle of talar tilt was smaller in those patients with a thickened ATFL than in those whose ATFL was thin or absent. However, a clear cut-off angle, which would allow discrimination between thickened and thin or absent, was not identified. These data are consistent with previous reports.[12,23]

MRI is commonly used as a less invasive technique for diagnosing acute lateral ankle ligament injury.[15,23,24] However, its use in CAI is controversial.[12,14,17] Cardone et al[17] examined 43 CAI patients and developed a set of diagnostic criteria in MRI for abnormalities of the ankle ligament. After comparing the results of stress radiography in 23 patients, they concluded that MRI is more useful than stress radiography for identifying injured ligaments. Chandnani et al[12] compared the efficacy of conventional MRI, MR arthrography, and stress radiography in 17 CAI patients and found that MRI has a sensitivity of 50% in the diagnosis of ATFL and CFL tears, which is similar to that of stress radiography. Oae et al[14] performed stress radiography, ultrasonography, MRI, and arthroscopy in 15 cases of chronic ankle sprains. Using arthroscopic results as the

gold standard, both MRI and stress radiography yielded 93% accuracy in ATFL injury diagnoses. The discrepancy between these two results may be due to the lack of common diagnostic criteria in MRI findings for ankle ligament injury, as well as differences in imaging protocols. In our study, maximum diameters of the ATFLs were measured from T2-weighted axial images in the neutral ankle position, as described by Cardone et al.[17] This protocol generates reproducible images, allowing objective evaluation of injured ligaments. In all of our cases, residual ATFLs were diagnosed as abnormal by pre-operative MRI and confirmed during surgery. The accuracy of ATFL injury diagnosis was higher or equal to those previously reported.[12,14,17]

Several studies have correlated imaging findings with surgical findings in CAI.[12,14,16,17] However, to the best of our knowledge, this is the first report to examine the use of MRI in the quantitative evaluation of residual ligamentous tissues in CAI patients. In this study, patients were categorised into three groups according to maximum diameters of residual ATFLs measured by pre-operative MRI. In all cases pre-operatively categorised as thickened, residual ligaments were thick enough to be advanced, as observed during surgery, and graft replacement was not required. In the remaining cases, we were unable to detect bulky or normal residual tissue, and reconstruction had to be performed.[25] Retrospectively, surgical procedures can be chosen according to the extent of residual ligamentous tissues predicted by pre-operative MRI. As the reconstruction procedure requires graft preparation, accurate pre-operative planning has substantial merit. In our study, the quantity of ATFLs were well evaluated. However, MRI evaluation of the quality of ligaments is difficult, partially due to the lack of a standard evaluation method. This is an issue to be addressed in future studies.

In conclusion, our results show that MRI is capable of quantitatively evaluating the injured ATFL. We believe that pre-operative MRI is useful as an adjunct to stress radiography in surgical planning.

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