



HAL
open science

Medial meniscal ossicles: Associated knee MRI findings in a multicenter case-control study.

Amandine Caudal, Daphné Guenoun, Guillaume Lefebvre, Jean-François
Nisolle, Gabriel Gorcos, Valérie Vuillemin, Bruno Vande Berg

► **To cite this version:**

Amandine Caudal, Daphné Guenoun, Guillaume Lefebvre, Jean-François Nisolle, Gabriel Gorcos, et al.. Medial meniscal ossicles: Associated knee MRI findings in a multicenter case-control study.. Diagnostic and Interventional Imaging, 2021, 102 (5), pp.321–327. 10.1016/j.diii.2020.11.013 . hal-03553381

HAL Id: hal-03553381

<https://hal.science/hal-03553381>

Submitted on 15 Apr 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Medial meniscal ossicles: Associated knee MRI findings in a multicenter case-control study

Amandine Caudal^a, Daphné Guenoun^{b,c}, Guillaume Lefebvre^d, Jean-François Nisolle^e, Gabriel Gorcos^f, Valérie Vuillemin^f, Bruno Vande Berg^{g,*}

^a Department of Radiology, CHU Pasteur 2, 06001 Nice cedex 1, France

^b Department of Radiology, Institute for Locomotion, Sainte-Marguerite Hospital, AP-HM, 13009 Marseille, France

^c CNRS, ISM, Institute Movement Sci, Aix-Marseille Université, 13000 Marseille, France

^d Department of Radiology & Musculoskeletal Imaging, Centre de consultation et d'imagerie de l'appareil locomoteur, CHU de Lille, 59037 Lille cedex, France

^e Department of Radiology, CHU UCL Namur IREC, 5530 Yvoir, Belgium

^f Centre d'Imagerie Médicale Léonard-de-Vinci, 75116 Paris, France

^g Department of Radiology, Institut de Recherche expérimentale et Clinique (IREC), Cliniques Universitaires Saint-Luc, Université Catholique de Louvain (UCLouvain), 1200 Brussels, Belgium

ARTICLE INFO

Keywords:

Knee joint

Magnetic resonance imaging (MRI)

Menisci, tibial

Meniscal ossicle

Anterior cruciate ligament

ABSTRACT

Purpose: The purpose of this study was to assess and compare the prevalence of meniscal, ligament and cartilage lesions on knee MRI in a series of age- and sex-matched patients with and without medial meniscal ossicle.

Materials and methods: Forty-two knee MRI examinations obtained in 42 patients (36 men, 6 women; mean age, 42.5 ± 22.2 [SD] years; range: 19–65 years) on which a medial meniscal ossicle was present were compared to 42 knee MRI examinations obtained in 42 age- and sex-matched patients (36 men, 6 women; mean age, 41.8 ± 20.6 [SD] years; range: 19–65 years) on which no medial meniscal ossicles were present. Two radiologists (R1, R2) blinded to the presence of meniscal ossicle by reading only the fat-saturated intermediate-weighted MR images separately assessed the presence of meniscal, ligament and cartilage lesions on these 84 knee MRI examinations. Prevalence of meniscal and ligament lesions and degree of cartilage degradation at MRI were compared between knees with and those without medial meniscal ossicle.

Results: In knees with medial meniscal ossicle, R1 and R2 detected 33 (79%) and 38 (90%) medial meniscal lesions, respectively that involved the posterior root ($n = 25/32$ for R1/R2), the posterior horn ($n = 19/14$ for R1/R2) or the body ($n = 8/10$ for R1/R2). The prevalence of posterior root tear (60% [25/42]/76% [32/42] for R1/R2) and that of anterior cruciate ligament (ACL) lesions (48% [20/42]/57% [24/42] for R1/R2) as well as the medial cartilage degradation score (3.35 ± 0.87 [SD] for R1 and 3.92 ± 0.78 [SD] for R2) were significantly greater in knees with than in knees without medial meniscal ossicle (root lesions: $P < 0.01$ for both readers; ACL lesions and medial cartilage score: $P < 0.01$ for both readers).

Conclusion: On MRI examination, knees with a medial meniscal ossicle demonstrate a greater frequency of medial posterior root tear and of ACL lesions and a greater degree of medial femoro-tibial cartilage degradation by comparison with knees without medial ossicle.

Abbreviations: ACL, Anterior cruciate ligament; ETL, Echo-train Length; FOV, Field of View; LCL, Lateral Collateral ligament; MCL, Medical Collateral ligament; MRI, Magnetic Resonance Imaging; PCL, Posterior Cruciate ligament; SE, Spin-Echo; TR, Repetition Time; TE, Echo-Time.

* Corresponding author.

E-mail address: bruno.vandenberg@uclouvain.be (B. Vande Berg).

1. Introduction

A meniscal ossicle is defined by the presence of an ossification within the substance of the meniscus. Initially described as a meniscal variant [1–3], case reports suggested that some meniscal ossicles were associated with posttraumatic meniscal lesions [4] or from an avulsion of the posterior root of the medial meniscus from the tibial spine [5]. Meniscal ossicle can be detected on radiography and on magnetic resonance imaging (MRI) [6–10]. Two previous non-controlled studies including a large number of MRI

examinations of knees with medial meniscal ossicle demonstrated that medial meniscal ossicle was associated with posterior horn and posterior root tears of the medial meniscus [11,12] and with anterior cruciate ligament (ACL) tears [11]. The importance in detecting meniscal ossicle is twofold. First, a meniscal ossicle should not be confused with an articular loose body as it is embedded in the meniscal substance and is less likely to produce articular impingement than a free loose body [13]. Second, presence of a meniscal ossicle most likely indicates a chronic meniscal lesion that is less likely to benefit from surgical repair than an acute meniscal avulsion [14].

In the two large non-controlled studies, knee MRI examinations were read in consensus by radiologists who were aware of the presence of a meniscal ossicle [11,12]. Therefore, we performed a study in which two separate radiologists blinded to the presence of the meniscal ossicle were asked to analyze a series of knee MRI examinations obtained in age- and sex-matched patients with and without medial meniscal ossicle.

The purpose of this study was to assess and compare the prevalence of meniscal, ligament and cartilage lesions at knee MRI in a series of age- and sex-matched patients with and without medial meniscal ossicle.

2. Materials and methods

2.1. Study population, definitions and data selection

The institutional review board of the organizing center (UCL Saint-Luc) approved this retrospective multicenter study and waived informed consent of the patients. During the 2017 Spring meeting of the Société d'Imagerie Musculo-Squelettique, 15 radiologists working in different imaging centers agreed to collect radiographic and MRI examinations of knees with a medial meniscal ossicle (study group) that had been obtained between January 2005 and December 2017 by using electronic research using

key-words including “os meniscal” and “ossicule” (French words used for meniscal ossicle) (Fig. 1a). They also agreed upon collecting radiographs and MRI examinations of knees from age- and sex-matched patients without meniscal ossicle (control group) that had been obtained during the same year as their study group knees (Fig. 1a). All eligible study and control group patients had knee symptoms to justify MRI examinations.

A meniscal ossicle was defined either by the presence of a well-delineated intrameniscal high signal intensity area on T1-weighted spin-echo (SE) MR images [6,8–12] or by the presence of a typical well-delineated ossification projecting in the medial femoro-tibial joint on radiographs [9,10]. Study group inclusion criteria were: (i), performance of MRI for internal derangement of the knee; (ii), age above 17 years; and (iii), presence of a meniscal ossicle at knee MRI and/or on available radiographs obtained within two months of the MRI examination. Exclusion criteria for the study group included: (i), lack of MRI examination; (ii), lack of non-fat-saturated T1-weighted SE sequence; and (iii), lack of fat-saturated intermediate-weighted MRI sequences. The lack of radiographs was not an exclusion criterion from the study group. Control group inclusion criteria were: (i), performance of knee radiographs and MRI examination for internal knee derangement within two-month interval; (ii), same age and gender as that of a patient of a study group; and (iii), lack of meniscal ossicle on knee radiographs and MRI examinations. The lack of radiographs was an exclusion criterion from the control group. Fourteen imaging centers provided 46 knees MRI examinations with possible medial meniscal ossicle with more than five MRI examinations in three imaging centers and 36 age- and sex-matched control knee MRI examinations. Radiographic and MRI examinations of the 10 missing control group MRI examinations were provided by a recruiting center that failed to find any study group knee.

Two radiologists with five (A.C.) and nine years (D.G.) of experience analyzed in consensus the radiographs and the T1-weighted MRI images of the study and the control group knees to confirm

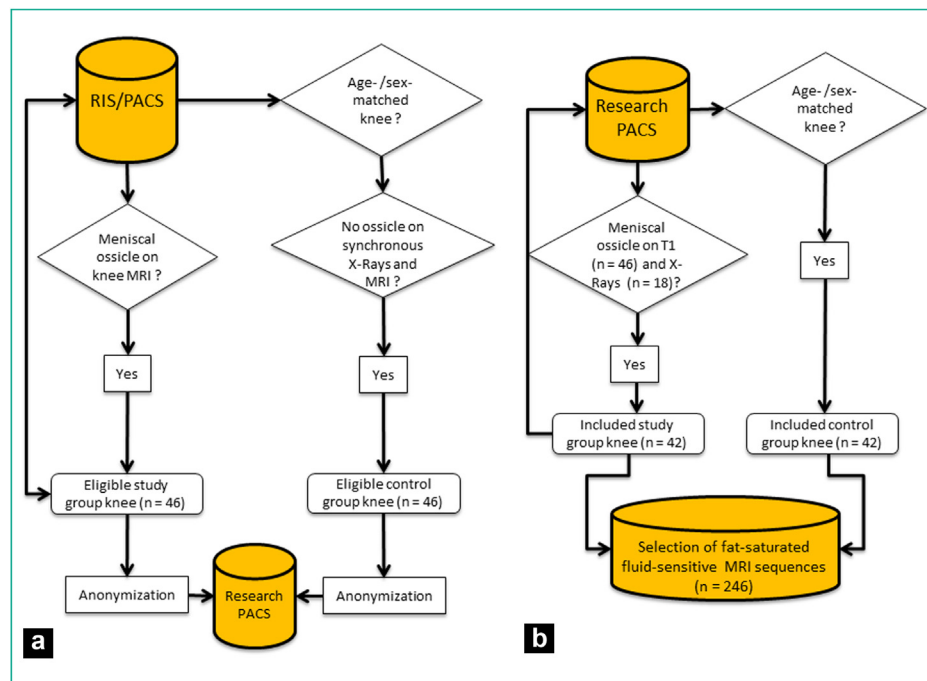


Fig. 1. (a) Flowchart illustrates the recruiting process performed in the 15 imaging centers to obtain imaging data of knees with meniscal ossicle (study group) and age- and sex-matched knees without meniscal ossicle. PACS indicates (b) flowchart illustrates the inclusion process performed by two radiologists who read the SE T1-weighted spin-echo MR images ($n = 46$) and available radiographs ($n = 25$) of eligible study group knees to exclude those which did not have a medial meniscal ossicle with a high degree of confidence. These two radiologists also determined the topography and the signal intensity of the meniscal ossicle at magnetic resonance imaging (MRI).

the presence or absence of a meniscal ossicle based on the above-mentioned definitions (Fig. 1b). Four study group knees and the four matched patients were excluded. The study population included 42 patients with a medial meniscal ossicle (36 men, 6 women; mean age, 42.5 ± 22.2 [SD] years; age range: 19–65 years) and 42 patients without medial meniscal ossicle (36 men, 6 women; mean age, 41.8 ± 20.6 [SD] years; age range: 19–65 years). They noted the location of the ossicle and its signal intensity that was considered to be either high or low, equivalent to or lower than that of adjacent marrow fat, respectively. MRI examinations were obtained on 1.5T (57/84; 68%) or on 3.0T MR units (27/84; 32%) by using dedicated knee coils in all imaging centers. Different MRI protocols were used due to variability among centers and time span of the study. All MRI examinations included at least one T1-weighted SE sequence obtained in the coronal (27/84; 32%) or sagittal (57/87; 68%) plane with the following parameters: repetition time (TR), 422–700 msec; echo-time (TE), 9–19 msec; echo-train length (ETL), 1–4; and flip angle, 76–150°. All MRI examinations included at least one fat-saturated intermediate-weighted sequence obtained in the coronal ($n = 84$), sagittal ($n = 78$) or transverse ($n = 84$) plane that were acquired in a two-dimensional (2D) acquisition mode or reformatted from a three-dimensional (3D) sequence. 2D MR images were obtained with the following parameters: TR, 1596–5440 msec; TE, 8–85 msec; ETL, 5–15; and flip angle, 90–130°. 3D MR images were obtained with the following parameters: TR, 800–1600 msec; TE, 37–44 msec; ETL, 32–48; and flip angle was 90°. All 2D images were obtained with a slice thickness of 2.5–4 mm and a field of view (FOV) between 14 and 20 cm. Reformatted images were obtained with a slice thickness of 2.0–4.0 mm and an FOV between 14 and 20 cm. Sixty (18 from study and 42 from control group) sets of antero-posterior and lateral knee radiographs were available. A data manager anonymized all fat-saturated intermediate-weighted sequences of the 84 knees and archived them on a picture and archiving communication system.

2.2. Image analysis

Two other radiologists with five (G.L., reader 1) and 27 (J.-F.N., reader 2) years of experience separately analyzed the available fat-saturated intermediate-weighted sequences of the 84 knees to detect meniscal, ligament and cartilage lesions by using standard diagnostic criteria on their standard 1 or 2 mega pixel workstations by connecting onto the central picture archiving and communication system. They were blinded to the clinical and radiographic data as well as to the T1-weighted sequences. They did not assess the presence or absence of a meniscal ossicle. A meniscal lesion was identified if there was increased signal intensity within the meniscus abutting an articular surface on two or more contiguous slices or associated change in morphology of the meniscus [15]. The meniscal tear was classified as simple or complex if there was only one or more than one plane of exit of the abnormal signal at its articular surface. The predominant meniscal lesion was located in the posterior meniscal root, posterior horn, body and anterior horn according to standard anatomic features. The posterior root of the medial meniscus is the most lateral aspect of that meniscus that inserts along the downward slope of the intercondylar fossa, anterior to the posterior cruciate ligament [15,16]. Peripheral meniscal extrusion is defined by medial translation of the meniscal body [15,17] and can be assessed by measuring the distance between the capsular margin of the body of the medial meniscus and the adjacent tibial plateau margin on coronal images [15,17]. Meniscal extrusion was defined by a measured distance equal or superior to 3 mm [15,17]. Presence or absence of lesion of anterior cruciate ligament (ACL), medial collateral ligament (MCL), lateral collateral ligament (LCL) and posterior cruciate ligament (PCL) were assessed according to standard lesion definition without grading of the lesions.

Any change of the ligaments including partial or complete tear and mucoid degeneration were considered to be abnormal. Modified Outerbridge's criteria were used to grade the articular cartilage in the femoral condyles and tibial plateaus [18]. Cartilage of the four articular surfaces was scored as follows: 0: normal cartilage; 1: less than 50% thickness loss; 2: more than 50% and less than 100% thickness loss; 3: down-to-bone thickness loss. Cartilage score of the medial and lateral femoro-tibial compartments were calculated by adding the scores of the corresponding femoral and tibial surfaces. Medial and lateral cartilage scores ranged from zero to six depending on the value of each of the two articular surfaces.

2.3. Statistical analysis

Statistical analysis was performed using dedicated software (MedCalc, version, Mariakerke, Belgium). Descriptive statistics were performed for the assessed variables in the study and control groups and compared by using Student *t*-test. Comparison of proportion of associated meniscal lesions were performed by using Chi square test. *P*-values < 0.05 were considered to indicate significant difference. Frequency analysis was performed on the location of a meniscal tear, in particular the posterior horn and root tears of the meniscus, and its relationship to the meniscal ossicle. Inter-observer agreement for the detection of meniscal and ligament lesions and for the scoring of cartilage by R1 and R2 in the series of 84 knee MRI examinations was determined by using Kappa statistics [19]. Strength of agreement was interpreted according to the Altman's scale as follows: kappa < 0.20 poor; 0.21 < kappa < 0.40, fair; 0.41 < kappa < 0.60, moderate; 0.61 < kappa < 0.80, good; kappa > 0.81 very good. Kappa values were calculated along with their 95% confidence intervals (CI).

3. Results

3.1. Medial meniscal ossicles and associated meniscal lesions

The 42 medial meniscal ossicles were located at the posterior root ($n = 34$), the posterior horn ($n = 7$) or anterior horn ($n = 1$) of the medial meniscus. On T1-weighted SE images, the signal intensity of the meniscal ossicle was equivalent to that of marrow fat in 38 ossicles (Figs. 2 and 3) and lower than that of marrow fat in four ossicles (Fig. 4). Among the 42 knees with a medial meniscal ossicle, R1 and R2 detected 34/42 (81%) and 38/42 (90%) medial meniscal lesions respectively that involved the posterior root ($n = 25$ for R1/32 for R2), the posterior horn ($n = 19$ for R1/ $n = 14$ for R2) or the body ($n = 8$ for R1/ $n = 10$ for R2) (Tables 1–3) (Figs. 2–4). There were no differences in frequency of root, posterior horn and body tears between meniscus with either root or posterior horn ossicle for each reader. R1 and R2 detected medial meniscus extrusion in 12 (28%) and in 15 (36%) (80%) study group knees respectively and in 7 (17%) and in 8 (19%) control group knees, respectively (Table 1). MRI findings in the control group knees are given in Tables 1 and 2. Inter-observer agreement was very good for the detection of lesions of the body of the medial meniscus (kappa = 0.856; 95% CI: 0.734–0.977) and was good for the detection of any medial meniscal lesions (kappa = 0.731; 95% CI: 0.580–0.881), of lesions of the posterior root (kappa = 0.730; 95% CI: 0.583–0.877) and of lesions of the posterior horn (kappa = 0.673; 95% CI: 0.511–0.836) of the medial meniscus.

3.2. Other MRI and clinical findings in study and control group knees

R1 and R2 detected lateral meniscal tears in 7/42 (17%) and 14/42 (33%) study group knees and in 5/42 (12%) and 7/42 (17%) control group knees, respectively (Table 1). They detected ACL

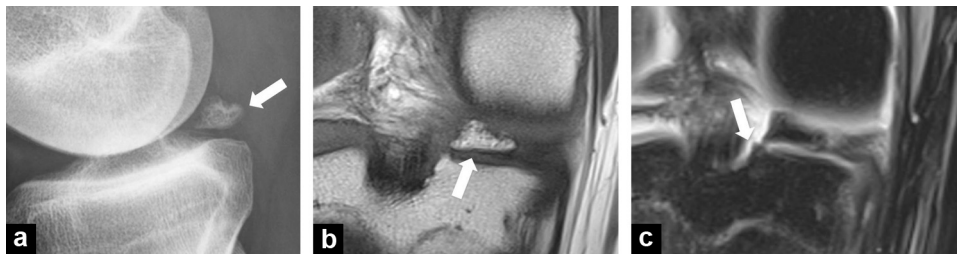


Fig. 2. Medial meniscal ossicle in a 19-year-old man: a: lateral radiograph of the right knee demonstrates a triangle-shaped osseous body (arrow) projecting on the posterior aspect of the femoro-tibial joint; b: coronal T1-weighted SE image demonstrates a triangle-shaped area of fat-like signal intensity in the lateral aspect of the posterior horn (arrow); c: on corresponding fat-saturated proton-density-weighted image, the ossicle has fat-like low signal intensity and is not visible. The posterior root of the medial meniscus (arrow) is torn. No meniscal extrusion was found.

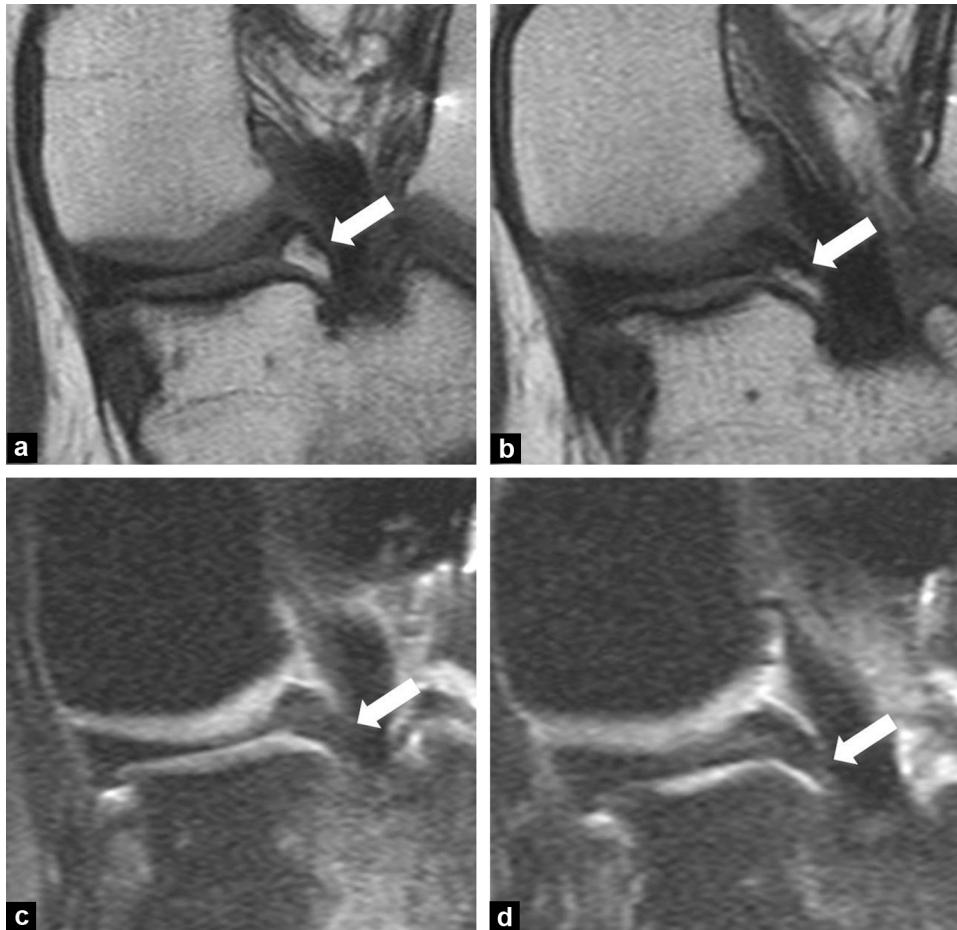


Fig. 3. Medial meniscal ossicle in a 36-year-old man: a, b: two posterior coronal T1-weighted SE images demonstrate a triangle-shaped intrameniscal fat-like signal intensity area (arrows); c, d: on the corresponding fat-saturated proton-density-weighted images, the ossicle shows moderate increase in signal intensity. The posterior root of the medial meniscus is normal at magnetic resonance imaging (MRI).

Table 1

Clinical and MRI findings in patients with a medial meniscal ossicle (study group) and in age- and sex-matched patients without medial meniscal ossicle (control group).

	Reader 1			Reader 2			Kappa	[95% CI]
	Study group	Control group	P	Study group	Control group	P		
Medial meniscus tear	34/42 (81%)	18/42 (43%)	<0.01	38/42 (90%)	24/42 (57%)	<0.01	0.731	[0.580–0.881]
Medial meniscus extrusion	12/42 (29%)	7/42 (17%)	0.19	15/42 (36%)	8/42 (19%)	0.08	0.873	[0.753–0.993]
Lateral meniscus tear	7/42 (17%)	5/42 (12%)	0.51	14/42 (33%)	7/42 (17%)	0.09	0.666	[0.472–0.860]
ACL lesion	20/42 (48%)	11/42 (26%)	0.03	24/42 (57%)	11/42 (26%)	<0.01	0.850	[0.736–0.965]
PCL lesion	2/42 (5%)	4/44 (10%)	0.38	2/42 (5%)	3/42 (7%)	0.70	0.708	[0.395–1.00]
MCL lesion	2/42 (5%)	2/42 (5%)	>0.99	7/42 (17%)	6/42 (14%)	0.70	0.429	[0.139–0.718]
LCL lesion	3/42 (7%)	1/42 (2%)	0.27	1/42 (2%)	2/42 (5%)	0.45	0.255	[-0.193 to 0.703]
Medial cartilage score	3.35 ± 0.87 [2–6]	2.85 ± 0.74 [2–6]	<0.01	3.92 ± 0.78 [2–6]	3.35 ± 0.71 [2–6]	<0.01	0.489	[0.346–0.632]
Lateral cartilage score	2.85 ± 0.75 [2–6]	2.47 ± 0.61 [2–6]	0.01	3.06 ± 0.72 [2–6]	2.88 ± 0.75 [2–6]	0.26	0.487	[0.328–0.647]

Qualitative variables are expressed as proportions; numbers in parentheses are percentages. Quantitative variables are expressed as means ± standard deviations; numbers in brackets are ranges. ACL: anterior cruciate ligament; PCL: posterior cruciate ligament; MCL: medial collateral ligament; LCL: lateral collateral ligament. Bold indicates significant P-value. CI: confidence interval.

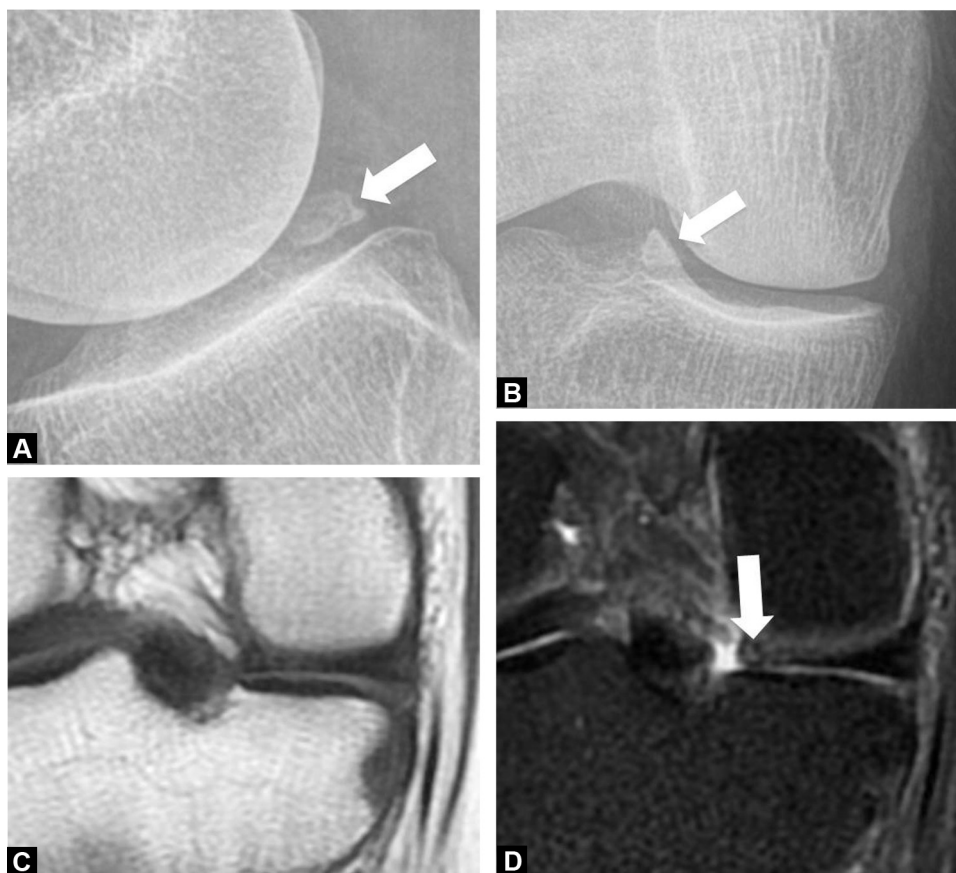


Fig. 4. Medial meniscal ossicle in a 65-year-old woman: a, b: knee radiographs demonstrate a triangle-shaped osseous body (arrows) located in the posterior aspect of the medial femoro-tibial joint; c: a coronal T1-weighted SE image demonstrates no signal abnormality of the medial meniscus; d: on the corresponding fat-saturated proton-density-weighted image, there is a tear of the posterior root. An area of intermediate signal intensity can be seen at the meniscal free edge (arrow) that probably corresponds to the ossicle. No meniscal extrusion was found.

Table 2

Comparison of the frequency of MRI lesion patterns and topography of the medial meniscus between patients with (study group) or without (control group) meniscal ossicle according to two radiologists (reader 1 and reader 2) who were blinded to the presence or absence of a medial meniscal ossicle.

	Reader 1			Reader 2		
	Study group	Control group	<i>P</i>	Study group	Control group	<i>P</i>
Posterior root						
Tear	25/42 (60%)	7/42 (17%)	< 0.01	32/42 (76%)	5/42 (12%)	< 0.01
Simple	21/42 (50%)	6/42 (14%)	< 0.01	25/42 (60%)	3/42 (7%)	< 0.01
Complex	4/42 (10%)	1/42 (2%)	0.12	7/42 (16%)	2/42 (5%)	0.03
Posterior horn						
Tear	19/42 (45%)	16/42 (38%)	0.51	14/42 (33%)	22/42 (52%)	0.08
Simple	13/42 (31%)	4/42 (14%)	0.06	10/42 (24%)	11/42 (26%)	0.83
Complex	6/42 (14%)	10/42 (24%)	0.24	4/42 (10%)	11/42 (26%)	0.06
Body						
Tear	8/42 (19%)	16/42 (38%)	0.06	10/42 (24%)	17/42 (40%)	0.11
Simple	4/42 (10%)	7/42 (17%)	0.35	8/42 (19%)	9/42 (21%)	0.81
Complex	4/42 (10%)	7/42 (17%)	0.35	2/42 (5%)	8/42 (19%)	0.05

Qualitative variables are expressed as proportions; numbers in parentheses are percentages. MRI: magnetic resonance imaging. Bold indicates significant *P*-value.

Table 3

Associations between location of ossicle and that of tears of medial meniscus for reader 1 and reader 2.

	Reader 1		<i>P</i>	Reader 2		<i>P</i>
	Root ossicle (n = 34)	Post. horn ossicle (n = 7)		Root ossicle (n = 34)	Post. horn ossicle (n = 7)	
Root tear	20/34 (59%)	5/7 (71%)	0.55	26/34 (76%)	6/7 (86%)	0.56
Post. horn tear	17/34 (50%)	2/7 (29%)	0.31	12/34 (35%)	2/7 (29%)	0.76
Body tear	6/34 (18%)	2/7 (29%)	0.51	7/34 (20%)	3/7 (43%)	0.19

Qualitative variables are expressed as proportions; numbers in parentheses are percentages. Post: posterior. The number of meniscal tears is higher than that of the meniscal ossicles because several segment of the meniscus can be torn. There was no difference in frequency of root, posterior horn and body tears between meniscus with either root or posterior horn ossicle for each reader. The ossicle involving the anterior horn is not included in this table.

lesions in 20/42 (48%) and 24/42 (57%) knees with meniscal ossicle (Table 1). Frequencies of other ligament lesions and medial and lateral cartilage scores for both readers are given in Table 1. The frequency of partial medial meniscectomy in the study group (4/42; 10%) was not different from that in the control group (1/42; 2%) ($P=0.12$). The frequency of ACL plasty in the study group (11/42; 26%) was not different from that in the control group (4/42; 14%) ($P=0.17$).

3.3. Comparison of MRI findings between knees with or without medial meniscal ossicle

The frequency of tear of the posterior root but not of that of the posterior horn or the body of the medial meniscus was statistically significantly higher in the study than in the control group knees ($P<0.01$ for R1 and R2) (Table 2). The frequency of medial meniscus extrusion was not different between the study group and control group (Table 1). The frequency of ACL lesions but not those of the other assessed ligaments was greater in the study than in the control group ($P<0.01$ for R1 and R2) (Table 1). The cartilage score of the medial femoro-tibial joint was greater in the study group than in the control group for both readers (Table 1). The cartilage score of the lateral femoro-tibial joint was greater in the study group than in the control group for one reader (Table 1).

4. Discussion

Ossicle within the knee meniscus is a rare finding at imaging, that has been studied in multiple case reports and two large series (Table 4) [4–12]. The current study confirmed the greater prevalence of medial posterior root tears and of ACL lesions in knees with medial meniscal ossicle than in knees without medial meniscal ossicle. This result, in line with those of previous studies, would suggest that a traumatic origin either due to a single trauma or multiple micro-traumatic events is likely to participate in the ossicle

development. In the current series, however, posterior root tear was less prevalent (60% for R1 and 76% for R2) than in the study of Bernard et al. (97.5%) suggesting that non-traumatic origin could still be possible (Table 4) [12]. The male predominance in our study population, which contrasts to the 1:1 sex ratio in the other two large studies (Table 4), is in favor of the traumatic hypothesis as knee injuries are more frequent in men [20] and knee osteoarthritis predominates in women [21].

In our study, we found no differences between the study group and control group in prevalence of posterior horn tear and meniscal extrusion. The former observation is in line with the rarity of the ossicle in comparison with the high frequency of posterior horn lesion. Most likely, other mechanisms than simple meniscal degeneration are needed to favor ossicle development. The latter observation could be related to the fact that meniscal extrusion is a non-specific finding associated with several meniscal, ligament and cartilage changes [16,17,22] that are frequently observed in an age- and sex-matched series without meniscal ossicle.

In our study, we observed more advanced medial cartilage loss in the study group than in the control group knees. Although it has been suggested that the ossicle itself could generate cartilage damage in the adjacent articular surface [7,8], the high prevalence in the study group of medial meniscal lesions and of ACL lesions prevents to draw any definitive conclusions regarding the direct causative role of the ossicle. Furthermore, medial posterior root tear is an important meniscal lesion that greatly affects knee biomechanics, predisposing the compartment to articular cartilage degeneration, subchondral insufficiency fractures and osteonecrosis [13,15,16].

Finally, the low signal intensity on fat- and fluid-sensitive sequences of four meniscal ossicles in our series has not been previously reported as meniscal ossicles consistently demonstrated fat-like signal intensity on MRI [4–12]. In the absence of histological specimen, it is not possible to determine whether this signal pattern reflects a high degree of mineralization or the presence of

Table 4
Study design, patient characteristics and MRI findings in the current study and in those of Mohankumar et al. [11] and Bernard et al. [12].

	Current study	Mohankumar et al.	Bernard et al.
Study design			
Case-control study	Yes	No	No
Recruiting centers	15	2	1
Inclusion period	2005–2017	2007–2012	2000–2018
Number of readers	2	3	2
Reading method	Independent	Consensus	Consensus
Blinding to meniscal ossicle	Yes	No	No
Patients			
Number of patients	84	65	59
Patients with medial ossicle	42/84 (50%)	58/65 (89%)	40 (68%)
Sex			
Male (%)	36/42 (86%)	33/65 (51%)	N.A.
Female (%)	6/42 (14%)	32/65 (49%)	N.A.
Age			
All patients with ossicles	42.5 ± 22 [19–65]	51.4 ± N.A. [23–80]	51 ± 19 [N.A.]
Men	42.9 ± 23 [19–62]	47.8 ± N.A. [23–80]	N.A.
Women	41.8 ± 16 [32–65]	55.0 ± N.A. [30–77]	N.A.
Prior meniscectomy	4/42 (10%)	4/58 (7%)	N.A.
ACL plasty	11/42 (26%)	14/58 (24%)	11/40 (27%)
MRI findings			
Posterior ossicle	41/42 (98%)	56/58 (97%)	39/40 (97%)
Ossicle with high signal on T1W	38/42 (90%)	58/58 (100%)	40/40 (100%)
Ossicle with low signal on T1W	4/42 (10%)	0/58 (0%)	0/40 (0%)
Medial meniscal tear	34/42 (81%)38/42 (90%)	57/58 (98%)	40/40 (100%)
Posterior root tear	25/42 (60%)32/42 (76%)	47/58 (81%)	39/40 (97.5%)
Posterior horn tear	19/42 (45%)14/42 (33%)	13/58 (22%)	1/40 (2.5%)
Body tear	8/42 (19%) 10/42 (24%)	0/58 (0%)	0/40 (0%)
ACL lesion	20/42 (48%)24/42 (57%)	31/65 (48%)	N.A.

MRI: magnetic resonance imaging; N.A.: not available; ACL: anterior cruciate ligament; T1W: T1-weighted images.

Qualitative variables are expressed as proportions; numbers in parentheses are percentages.

Quantitative variables are expressed as means ± standard deviations; numbers in brackets are ranges.

tissue associated with osseous metaplasia that does not contain fat until maturity has been reached [23].

The current study has several limitations in addition to its retrospective design and to the identification of eligible patients by using keywords as in the two previous large studies [11,12]. First, blinding of the readers to the presence or absence of meniscal ossicle was achieved by disabling them to analyze the radiographs, the T1-weighted and the non-fat-saturated fluid-sensitive sequences. We cannot exclude that they could have seen some intrameniscal signal changes suggestive of a meniscal ossicle although they were not asked to search for ossicle and intrameniscal signal intensity changes. The lack of conspicuity of meniscal ossicle on fat-saturated images should also be taken into consideration when using artificial intelligence for detecting meniscal lesions based on fat-saturated sequence only [24,25]. A second limitation is the lack of reliable previous clinical history and of body mass index. This limitation is inherent to the large number of recruiting centers. Third, there was no arthroscopic demonstration of the meniscal ossicle and of the other knee lesions. Our reference standard for the presence or absence of a meniscal ossicle relied on the analysis of the radiographs and MR images of 46 eligible knees and the corresponding control group. Four eligible knees were excluded because the presumed ossicles were not in the meniscal substance and corresponded to intra-articular osteo-cartilaginous bodies. Presence of an ossicle was defined by the presence of high signal intensity within the meniscal substance and/or the presence of a bony nodule on the 18 sets of radiographs from the study group. Absence of a meniscal ossicle was defined by the lack of meniscal high signal intensity on T1-weighted images and the lack of osseous nodule on the 42 sets of radiographs from the control group. Finally, sequence acquisition parameters and image planes varied among MRI examinations because they were provided by several imaging centers over a 12-year inclusion period.

In conclusion, on MRI, knees with medial meniscal ossicle are associated with a greater prevalence of medial posterior root tear, ACL lesions and ipsilateral cartilage degradation but not with posterior horn lesions and meniscal extrusion than knees without meniscal ossicle in an age- and sex-matched population.

Human rights

The authors declare that the work described has been carried out in accordance with the Declaration of Helsinki of the World Medical Association revised in 2013 for experiments involving humans.

Informed consent and patient details

The authors declare that this report does not contain any personal information that could lead to the identification of the patients.

Funding

This work did not receive any grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author contributions

All authors attest that they meet the current International Committee of Medical Journal Editors (ICMJE) criteria for Authorship.

Acknowledgment

We thank the following radiologists for participating in the current study by searching for and providing study and control

cases: Loic Bouilleau (Tours), Joseph Yazbek (Bordeaux), Celine Brun (Lyon), Marine Brunet (Toulouse), Yannick Carillon (Lyon), Benjamin Dallaudière (Bordeaux), Frederic Defaux (Poitiers), Marie-Laurence Denis (Liège), Guillaume Etievent (Saint-Étienne), Marie Faruch-Bielfeld (Toulouse), Romain Gillet (Nancy), Patrick Omoumi (Lausanne), Jean-Noel Ravey (Grenoble), Nor-Eddine Regnard (Paris), Jerome Renoux (Paris), Flore Viry (Paris), Arnaud Monnier (Montreal), Quentin Monzani (Paris). We also thank Perrine Triqueneaux for technical and secretarial assistance.

Disclosure of interest

The authors declare that they have no competing interest.

References

- [1] Harris HA. Calcification and ossification in the semilunar cartilages. *Lancet* 1934;223:1114–6.
- [2] Jones RW, Roberts RE. Calcification, decalcification, and ossification. *Proc R Soc Med* 1933;21:461–99.
- [3] Burrows HJ. Two cases of ossification in the internal semilunar cartilage. *Br J Surg* 1934;21:404–10.
- [4] Yoo JH, Yang BK, Son BK. Meniscal ossicle: a case report. *Knee* 2007;14:493–6.
- [5] Berg EE. The meniscal ossicle: the consequence of a meniscal avulsion. *Arthroscopy* 1991;7:241–3.
- [6] Yu JS, Resnick D. Meniscal ossicle: MR imaging appearance in three patients. *Skeletal Radiol* 1994;23:637–9.
- [7] Yao J, Yao L. Magnetic resonance imaging of a symptomatic meniscal ossicle. *Clin Orthop Relat Res* 1993;293:225–8.
- [8] Tuite MJ, De Smet AA, Swan JS, Keene JS. MR imaging of a meniscal ossicle. *Skeletal Radiol* 1995;24:543–5.
- [9] Schnarkowski P, Tirman PF, Fuchigami KD, Crues JV, Butler MG, Genant HK. Meniscal ossicle: radiographic and MR imaging findings. *Radiology* 1995;196:47–50.
- [10] Martinoli C, Bianchi S, Spadola L, Garcia J. Multimodality imaging assessment of meniscal ossicle. *Skeletal Radiol* 2000;29:481–4.
- [11] Mohankumar R, Palisch A, Khan W, White LM, Morrison WB. Meniscal ossicle: posttraumatic origin and association with posterior meniscal root tears. *AJR Am J Roentgenol* 2014;203:1040–6.
- [12] Bernard DC, McGauvran AM, Desai VS, Frick MA, Tiegs-Heiden C, Camp CLA, et al. Understanding the implications of the meniscal ossicle: patient presentation, treatment and outcomes. *J Knee Surg* 2019, <http://dx.doi.org/10.1055/s-0039-1693724>.
- [13] Gursoy M, Dirim Mete B, Dag F, Bulut T. The distribution of loose bodies determined on knee magnetic resonance imaging: joint compartments, recesses and bursae including arthroscopic blind spots. *Acta Radiol* 2019;60:1286–93.
- [14] Palisch AR, Winters RR, Willis MH, Bray CD, Shybut TB. Posterior root meniscal tears: preoperative, intraoperative, and postoperative imaging for trans tibial pullout repair. *Radiographics* 2016;36:1792–806.
- [15] Nguyen JC, De Smet AA, Graf BK, Rosas HG. MR imaging-based diagnosis and classification of meniscal tears. *Radiographics* 2014;34:981–99.
- [16] Lee SY, Jee WH, Kim JM. Radial tear of the medial meniscal root: reliability and accuracy of MRI for diagnosis. *AJR Am J Roentgenol* 2008;191:81–5.
- [17] Liu Y, Du G, Li X. Threshold for lateral meniscal body extrusion on MRI in middle-aged and elderly patients with symptomatic knee osteoarthritis. *Diagn Interv Imaging* 2020;101:677–83.
- [18] Curl WW, Krome J, Gordon ES, Rushing J, Smith BP, Poehling GG. Cartilage injuries: a review of 31,516 knee arthroscopies. *Arthroscopy* 1997;13:456–60.
- [19] Benchoufi M, Matzner-Lober E, Molinari N, Jannot AS, Soyer P. Interobserver agreement issues in radiology. *Diagn Interv Imaging* 2020;101:639–41.
- [20] Thein R, Hershkovich O, Gordon B, Burstein G, Tenenbaum S, Derazne E, et al. The prevalence of cruciate ligament and meniscus knee injury in young adults and associations with gender, body mass index, and height: a large cross-sectional study. *J Knee Surg* 2017;30:565–70.
- [21] Cross M, Smith E, Hoy D, Nolte S, Ackerman J, Fransen M, et al. The global burden of hip and knee osteoarthritis: estimates from the global burden of disease 2010 study. *Ann Rheum Dis* 2014;73:1323–30.
- [22] Lerer DB, Umans HR, Hu MX, Jones MH. The role of meniscal root pathology and radial meniscal tear in medial meniscal extrusion. *Skeletal Radiol* 2004;33:569–74.
- [23] Foley KL, Hebel N, Keenan MA, Pignolo RJ. Histopathology of periarticular non-hereditary heterotopic ossification. *Bone* 2018;109:65–70.
- [24] Couteaux V, Si-Mohamed S, Nempont O, Lefevre T, Popoff A, Pizaine G, et al. Automatic knee meniscus tear detection and orientation classification with Mask-RCNN. *Diagn Interv Imaging* 2019;100:235–42.
- [25] Roblot V, Giret Y, Bou Antoun M, Morillot C, Chassin X, Cotten A, et al. Artificial intelligence to diagnose meniscus tears on MRI. *Diagn Interv Imaging* 2019;100:243–9.