MRI of the knee cost-efffective use

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CHAPTER 6

Clinical consequences of bone bruise around the knee

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6.1. Abstract

Objective The aim of this study is to evaluate the relation between bone bruise and (peri-)articular derangement and to assess the impact of bone bruise on presentation and short term course of knee complaints.

Materials and methods We recorded MR abnormalities in 664 consecutive patients with sub-acute knee complaints. Patients were divided in four groups: patients with and without intra-articular knee pathology, subdivided in patients with and without bone bruise. We assessedfunction and symptoms at the time of MR and 6 months thereafter.

Results Bone bruises were diagnosed in 124 of 664 patients (18.7%). Patients with bone bruise had significantly more complete ACL, lateral meniscal, MCL and LCL tears. Both with and without intraarticular pathology patients with bone bruise had a significantly poorer function at the time of MR (Noyes score of, respectively, 313.21 versus 344.81 and 306.98 versus 341.19). Patients with bone bruise and intraarticular pathology showed significantly more decrease in activity (decrease of Tegner score from 6.28 to 2.12 versus 5.70–2.55). At 6 months there were no significant differences in clinical parameters between the four groups.

Conclusion We concluded that bone bruise in combination with MCL tear is an important cause of initial clinical impairment in patients with sub-acute knee complaints. Clinical improvement within 6 months is more pronounced than in patients without bone bruise.

6.2. Introduction

With the advent of magnetic resonance (MR) imaging bone bruise was introduced as a new radiologic diagnosis [1, 2]. A bone bruise is defined as a traumatically involved geographic, and non-linear area of signal loss involving the subcortical bone on T1-(short TE) weighted images and increased signal intensity on T2-weighted images. The term 'bruise" indicates the traumatic origin of these bone marrow changes. These signal alterations are thought to represent trabecular (micro-) fractures associated with edema and hemorrhage. MR imaging findings are therefore also referred to as bone marrow edema pattern. The clinical relevance of this finding has been an issue of discussion ever since the first reports on bone bruise. Clinically, bone bruises can have the same symptoms as meniscal or other intra-articular injury. Traumatic events resulting in bone bruise and/or intra-articular injury are also similar. Therefore, bone bruises may trigger decisions to perform arthroscopy in patients without internal derangement of the knee [3]. On the other hand, there also is an association between bone bruise and intra-articular pathology [4-9].

The aim of this prospective multicenter study is to evaluate the relation between bone bruise and (peri-)articular derangement and to assess the impact of bone bruise on presentation and short term course of knee complaints inpatients with clinically suspected internal derangement of the knee. We addressed this issue using a general MR knee protocol that is commonly used, rather than a dedicated protocol with a higher sensitivity to bone bruise.

6.3. Materials and methods

6.3.1. Patients and study design

In this prospective multicenter study, primarily designed to evaluate the efficacy of MR compared to direct arthroscopy, all consecutive patients, aged between 16 and 45 years, with at least 4 weeks of knee complaints, consisting of pain, swelling, instability and/or locking of the knee, who were referred to the departments of Orthopedics or Surgery of three unaffiliated hospitals (one university and two general hospitals) were eligible. In all three participating hospitals, the study received approval of the Institutional Review Board (IRB).

Informed consent was obtained from 962 patients. All these patients had standardized physical examination and antero-posterior and lateral radiographs of the knee. Patients were included if internal derangement was suspected based on the presence of at least one of the following clinical abnormalities: the presence of marked joint effusion or at least a 'bulge sign' (ie a visible bulge next to the patella caused by displacement of fluid and indicative for effusion); an extension deficit of at least 10°;

a flexion deficit of at least 20°; instability (varus and valgus stress, Lachman, anterior and posterior drawer and Pivot test); at least one positive meniscal provocation test (McMurray, Apley and squat test); and atrophy of at least 2 cm relative to the contralateral leg measured 15 cm above medial joint-line. Because of the criterion of at least 4 weeks of complaints, acute trauma was not included, whereas patients with chronic trauma could be included.

Exclusion criteria were known joint disease (for instance rheumatoid arthritis), pathology diagnosed earlier with MR imaging, contra-indication for MR imaging (claustrophobia, pacemaker) or arthroscopy, locked knee at presentation, recurrent locking of the knee in combination with extension deficit and/or positive McMurray test, prior surgery of the knee, a radiographically confirmed fracture, severe osteoarthritis of the knee (Kellgren grade 4) and a clinical diagnosis of retro-patellar chondromalacia. These patients were excluded because MR imaging will not play a role in the decision to perform arthroscopy either because arthroscopy will be performed on clinical criteria alone or because arthroscopy is contraindicated.

Ultimately 664 of 962 patients met our criteria and were included. All these patients underwent subsequent MR imaging within 2 weeks after inclusion. Of the 664 included patients in our study, 460 (69.3%) were male. The median age was 31.0 years.

As mentioned above, the study design was not tailored towards the issue of bone bruises only, because the overall goal of this multicenter study was to evaluate the efficacy of MR compared to direct arthroscopy in patients with subacute knee complaints, based on clinical outcome. The treatment following inclusion was determined by the MR diagnosis (see MR evaluation). Patients with abnormal intra-articular findings on MR proceeded to arthroscopy. Patients without intra-articular MR abnormalities were randomized over two treatment strategies. Half of these patients had arthroscopy, the other half were treated conservatively. This data set was subsequently also used to address the issue of bone bruises.

For the purpose of determining the influence of bone bruise on clinical presentation and course of complaints in patients with and without intra-articular knee pathology we divided patients in two groups: patients with and patients without relevant intra-articular knee pathology. We considered as relevant intra-articular knee pathology: all meniscal tears, complete anterior and posterior cruciate ligament tears, chondromalacia grade 3 or 4, osteochondritis dissecans with cartilage fissure or loose body.
In the patients who underwent arthroscopy (with or without positive MR diagnosis) the arthroscopic and not the MR diagnosis was used to categorize a patient as having intra-articular injury or not. In patients without arthroscopy the MR diagnosis was used to categorize the patient. Ultimately, 273 patients had no intra-articular pathology (152 based on arthroscopic findings, 121 based on MR findings), while 391 patients had internal derangement (345 based on arthroscopic findings, 46 based on MR findings).We identified in each of the two categories the patients with bone bruises.

6.3.2. MR imaging

In all three hospitals, we performed MR imaging with an identical 0.5-T system (Gyroscan T5; Philips Medical Systems, Best, the Netherlands), with the same software release (Release 3; Philips Medical Systems) using a dedicated transmit-receive knee coil.

The standardized scanning protocol was designed to address internal derangement and not bone bruise in particular and consisted of three sequences: a sagittal and a coronal dual spin-echo (SE) sequence and a sagittal T1-weighted three-dimensional gradient-echo sequence with frequency-selective fat suppression. The following parameters were identical for both SE sequences: 140-160 mm field of view and 20 and 80 ms echo times. The coronal dual SE had a repetition time of 2100 ms, a matrix of 256×205 and a section thickness of 5 mm with a 0.5 mm intersection gap. The sagittal dual SE had a repetition time of 2350 ms, a matrix of 256×179 and a section thickness of 4 mm with a 0.4 mm intersection gap. The parameters for the sagittal frequency-selective fat suppressed T1-weighted three-dimensional gradient-echo sequence were: repetition time ms/echo time ms, 70/13; flip angle, 45°; field of view, 160 mm; matrix, 256×205; and section thickness, 4 mm with 2 mm overlap.

The total imaging time of the standard protocol, including the initial survey sequence was 26 min.

6.3.3. MR evaluation

A group of six radiologists (W.M.C.M., E.G.C., J.L.B.) experienced in musculoskeletal imaging was available for reading MR images. Each MR study was prospectively and individually evaluated by one radiologist. We decided to accept the ensuing variation between observers because we preferred to follow real life clinical practice as closely as possible. After the radiologist had recorded his findings on a standardized case record form (CRF), he categorized the MR diagnosis depending on the observed pathology. We defined three categories (Table 1): category 1: normal MR examination or pathology not needing arthroscopic treatment; category 2: equivocal pathology; in these patients the orthopedic surgeon decided based on MR and clinical findings to perform arthroscopy or not; and category 3: pathology requiring arthroscopy.

The presence of bone bruise or bone marrow edema pattern, including the location, was also recorded. Bone bruise or bone marrow edema pattern were, irrespective of etiology, grouped together under the title of bone bruise. A bone bruise was defined as an ill defined geographic, and non-linear area of signal loss involving the subcortical bone on intermediate (short echo time) weighted images and increased signal intensity on T2-weighted images (2). On fat-suppressed T1-weighted images, these areas show increased signal intensity compared to suppressed normal fatty bone marrow. Small bone bruises that can only be detected using dedicated STIR-sequences were ignored.

We distinguished bone bruises from radiographic occult fractures using previously described criteria (linear areas of signal loss involving the subcortical bone with or without cortical interruption and osteochondral fractures)[4, 10]. These occult fractures were separately recorded.

Table 1
Classification of pathology on MR. Category 1 normal MR examination or pathology not needing arthroscopic treatment; category 2 equivocal pathology; category 3 pathology requiring arthroscopy, OD osteochondritis dissecans; PVNS pigmented villonodular synovitis

	Category 1	Category 2	Category 3
Menisci (Classification according to Lotysch)	Normal Meniscal tear < 5mm Meniscal degeneration without tear Discoid meniscus		Meniscal tear ≥ 5mm Meniscal cyst
Cartilage (Classification according to Recht)	Normal Chondromalacia grade 1-3 Non-isolated chondromalacia grade 4 Isolated chondromalacia grade 4 of a none-weight bearing surface	OD with intact cartilage	Isolated chondromalacia grade 4 of a weight bearing surface OD with cartilage fissure Loose body
Cruciate ligaments	Normal Acute isolated tear cruciate ligament Partial tear cruciate ligament	Chronic tear cruciate ligament with instability	Tear cruciate ligament in combination with meniscal tear
Collateral ligaments	Normal Isolated tear collateral ligament	Tear collateral ligament with capsule-lesion	Tear collateral ligament in combination with meniscal tear
Synovia	Normal Plica Synovitis		Intra-articular PVNS
Other structures	Normal Bone bruise	Tumor Extra-articular PVNS	

6.3.4. Assessment of function and symptoms

One of two research physicians (B.P.M.t.B., P.W.J.V.) assessed function and symptoms during an interview at the time of MR and 6 months thereafter, using Noyes scale for function (range: 200 [poor]-550 [good]) and symptoms (range: 0 [poor] - 400 [good]) (see Appendix 1)[11, 12]. In addition, we recorded, using a structured interview, the level of activity before the onset of complaints (in retrospect), at the time of MR and 6 months thereafter. To this end, we used the Tegner activity scale (range: 10 [competitive sports]-0 [sick leave]) (see Appendix 1)[13, 14]. History of traumatic events was also recorded.

6.3.5. Arthroscopy

All arthroscopies were videotaped and performed in one of the three participating hospitals by an experienced (orthopedic) surgeon or a trainee supervised by a (orthopedic) surgeon. The scope was introduced in the knee through an antero-lateral or transpatellar portal, using an arthroscope with 30° viewing angle. All structures were not only visualized, but also probed if necessary.

6.3.6. Data analysis

In two categories of patients (with and without intra-articular knee pathology) we compared patients with and without bone bruise. With an independent samples t-test we compared both Noyes and Tegner scales at the time of MR and 6 months thereafter. We also evaluated the influence of individual (peri-)articular pathology on the Noyes and Tegner scales at the time of MR and 6 months later.

With univariate variance analysis, we evaluated the influence of bone bruise and other (peri-)articular pathology on the Noyes function and symptoms score and Tegner activity score at the time of MR and 6 months later.

6.4. Results

Bone bruises (Fig. 4) were diagnosed in 124 of 664 patients (18.7%). In addition, radiographically occult fractures (Fig. 5) were diagnosed in five patients (three patients without, two with concomitant intra-articular knee pathology). These five patients were not included in the analysis. Thus remained 659 patients in the analysis.

A traumatic event was reported in 106 of 124 patients with bone bruise (85.5%). In 535 patients without bone bruise, 308 (57.5%) reported a trauma prior to the start of their knee complaints. This difference in incidence of traumatic events between patients with and without bone bruise is significant ($P < 0.001$).

Eighty-one out of 389 patients (20.8%) with intra-articular pathology had bone bruise(s). Of these 81 patients, 36 (44.4%) had a bone bruise in one location. Twenty-nine patients (35.8%) had two bone bruises and 16 (19.8%) had more than two bone bruises. Bone bruises were located in the lateral femoral condyle in 44 patients (54.3%), in the lateral tibial plateau in 43 (53.1%), in the medial tibial plateau in 31 (38.3%), in the medial femoral condyle in 27 (33.3%), in the patella in six (7.4%) and intercondylar in one patient (1.2%).

Forty-three out of 270 patients (15.9%) without intraarticular pathology had bone bruise(s). Of these 43 patients, 29 (67.3%) had a bone bruise in one location. Eleven patients (25.6%) had two bone bruises and three (7.0%) had more than two bone bruises. Bone bruises were located in the lateral tibial plateau in 20 patients (46.5%), in the lateral femoral condyle in 16 (37.2%), in the medial tibial plateau in 11 (25.6%), in the patella in eight (18.6%), in the medial femoral condyle in six (14.0%) and intercondylar in one patient (2.3%).

In patients with intra-articular pathology, the number of bone bruises per patient was significantly higher than in patients without intra-articular pathology ($P = 0.034$).

Table 2 lists intra- and peri-articular abnormalities in patients with and without bone bruise. Patients with bone bruise did not have significantly more intra-articular injuries than patients without bone bruise (81 of 124 patients or 65.3% versus 308 of 535 patients or 57.6%, $P = 0.129$). However, patients with bone bruise had significantly more complete anterior cruciate ligament tears ($p = 0.001$) and lateral meniscal tears ($P = 0.033$) than patients without bone bruise. Of the peri-articular injuries both (partial) medial collateral ligament tears ($P < 0.001$) and (partial) lateral collateral ligament tears ($P < 0.001$) occurred significantly more frequent in patients with bone bruise (Table 2). We found no patients with complete medial or lateral collateral ligament tears. In Table 3, we provide the most frequent pathology of individual structures with the function, symptoms and activity scores.

Table 2
Articular and peri-articular abnormalities in relation to presence or absence of bone bruise. Data on seven subgroups of five of the main injuries (medial meniscal tear, lateral meniscal tear, ACL tear, MCL tear, LCL tear and chondromalacia) are given in italics. *n* number of patients, percentage (%) in parenthesis; * significant differencebetween groups

	No bone bruise	Bone bruise	p
N	535	124	
Intra-articular knee pathology	308 (57.6)	81 (65.3)	0.129
Medial meniscal tear	191 (35.7)	45 (36.3)	0.917
Lateral meniscal tear	96 (17.9)*	33 (26.6)*	0.033
Tear in both menisci	27 (5.0)	10 (8.1)	0.195
ACL tear	50 (9.3)*	26 (21.0)*	0.001
Isolated ACL tear	21 (3.9)	10 (8.1)	0.024
ACL combined with meniscal tear	29 (5.4)	16 (12.9)	0.016
Chondromalacia	71 (13.3)	17 (13.7)	0.884
MCL tear	85 (15.9)*	55 (44.4)*	<0.001
MCL tear (with intra-articular pathology)	59 (19.2)*	38 (46.9)*	<0.001
MCL tear (without intra-articular pathology)	26 (11.5)*	17 (39.5)*	<0.001
LCL tear	8 (1.5)*	10 (8.1)*	<0.001
LCL tear (with intra-articular pathology)	8 (2.6)	5 (6.2)	0.154
LCL tear (without intra-articular pathology)	0 (0.0)*	5 (11.6)*	<0.001

6.4.1. Clinical evaluation in patients with intra-articular pathology

At the time of MR, patients with bone bruise had a significantly poorer function than patients without bone bruise (P = 0.001; Table 4, Figs. 1, 2, 3). Although symptoms and activity were not significantly different at the time of MR, the decrease in activity level relative to the level of activity before onset of complaints of patients with bone bruise was significantly larger (P = 0.003) than in patients without bone bruise, because of a (not significant) higher activity level before onset of complaints (decrease from 6.28 to 2.12 in patients with bone bruise and from 5.70 to 2.55 in patients without bone bruise).

Table 3
Pathology of individual structures in relation to clinical parameters. *n* number of patients; SD standard deviation

	Noyes function score at time of MRI	Noyes function score six months after MRI	Noyes symptom score at time of MRI	Noyes symptom score six months after MRI	Tegner score before onset of complaints	Tegner score at time of MRI	Tegner score six months after MRI
Medial meniscal tear							
Yes (N = 236)	341.40 (SD 68.75)	436.32 (SD 83.56)	243.61 (SD 86.79)	348.84 (SD 76.64)	5.74 (SD 2.41)	2.42 (SD 2.13)	4.16 (SD 2.28)
No (N = 423)	334.86 (SD 65.56)	414.68 (SD 78.93)	232.21 (SD 88.05)	330.47 (SD 85.32)	5.64 (SD 2.48)	2.43 (SD 2.25)	4.06 (SD 2.23)
Lateral meniscal tear							
Yes (N = 129)	331.55 (SD 62.66)	415.31 (SD 80.09)	228.99 (SD 85.04)	328.85 (SD 85.48)	6.02 (SD 2.58)	2.46 (SD 2.07)	3.67 (SD 2.23)
No (N = 530)	338.58 (SD 67.70)	424.33 (SD 85.69)	238.12 (SD 88.34)	339.21 (SD 81.93)	5.60 (SD 2.42)	2.42 (SD 2.24)	4.20 (SD 2.25)
ACL tear							
Yes (N = 76)	340.00 (SD 64.00)	429.68 (SD 74.36)	244.21 (SD 70.83)	345.08 (SD 61.48)	7.17 (SD 1.98)	2.91 (SD 2.27)	4.26 (SD 2.22)
No (N = 583)	336.84 (SD 67.15)	421.66 (SD 85.83)	235.25 (SD 89.71)	336.18 (SD 84.93)	5.48 (SD 2.44)	2.36 (SD 2.20)	4.08 (SD 2.26)
MCL tear							
Yes (N = 140)	327.93 (SD 65.48)	424.04 (SD 84.09)	250.50 (SD 80.01)	335.26 (SD 81.68)	6.26 (SD 2.34)	2.32 (SD 2.18)	4.44 (SD 2.28)
No (N = 519)	339.71 (SD 67.00)	422.13 (SD 84.92)	232.34 (SD 89.44)	337.50 (SD 83.04)	5.53 (SD 2.46)	2.45 (SD 2.22)	4.01 (SD 2.24)
LCL tear							
Yes (N = 18)	301.67 (SD 53.16)	440.67 (SD 97.50)	234.44 (SD 81.98)	325.33 (SD 111.73)	5.67 (SD 2.93)	1.83 (SD 1.86)	4.87 (SD 2.33)
No (N = 641)	338.18 (SD 66.95)	421.93 (SD 84.41)	236.53 (SD 87.98)	337.29 (SD 81.94)	5.68 (SD 2.45)	2.44 (SD 2.22)	4.08 (SD 2.25)

Patients in both groups (with and without bone bruise) had significantly improved function, symptoms and activity 6 months after MR (P = 0.001 for all three scores). There were no significant differences between the two groups for the three parameters at 6 months (Table 4). There also were no differences between the two groups in amount of improvement of the three clinical parameters measured over 6 months.

Table 4
MR findings in relation to clinical parameters. *n* number of patients; SDstandard deviation

	No intra-articular knee pathology		Intra-articular knee pathology	
	No bone bruise	Bone bruise	No bone bruise	Bone bruise
N	227	43	308	81
Number of patients available at follow up	201	35	268	69
Noyes function score at time of MRI	341.19* (SD 66.08)	306.98* (SD 55.44)	344.81* (SD 67.59)	313.21* (SD 61.86)
Noyes function score six months after MRI	415.00 (SD 89.62)	436.18 (SD 78.93)	427.57 (SD 81.78)	418.26 (SD 82.72)
Noyes symptom score at time of MRI	234.53 (SD 89.14)	213.81 (SD 86.95)	243.82 (SD 88.01)	224.50 (SD 80.63)
Noyes symptom score six months after MRI	328.14 (SD 85.61)	350.86 (SD 84.76)	342.76 (SD 79.38)	334.49 (SD 84.57)
Tegner score before onset of complaints	5.46 (SD 2.45)	5.58 (SD 2.67)	5.70 (SD 2.44)	6.28 (SD 2.34)
Tegner score at time of MRI	2.39 (SD 2.33)	2.33 (SD 2.40)	2.55 (SD 2.12)	2.12 (SD 2.07)
Tegner score six months after MRI	4.10 (SD 2.29)	4.71 (SD 2.42)	4.08 (SD 2.24)	3. 88 (SD 2.06)

*Significant difference between patients with or without bone bruise within the category intra-articular knee pathology and within the category intra-articular knee pathology. In each group all scores improved significantly after 6 months

The initial clinical differences between patients with and without bone bruise, as mentioned above, were not associated with tears in ACL, lateral meniscus and collateral ligaments, that were more frequent in patients with bone bruise.

Both in patients with and without bone bruises that underwent arthroscopy (respectively 70 patients [86%] and 273 patients [89%]) the fraction of therapeutic arthroscopies (ie an arthroscopy during which an intervention with therapeutic intentions was performed) was almost equal: respectively 86% (60 patients) and 88% (240 patients).

6.4.2. Clinical evaluation in patients without intra-articular pathology

At the time of MR, patients with bone bruise had the same level of activity and symptoms, but significant (P = 0.002) lower level of function compared to patients without bone bruise (Table 4, Figs. 1, 2, 3). The decrease in activity level relative to the level of activity before onset of complaints was not significantly different between both groups.

Patients in both groups (with and without bone bruise) had significantly improved function, symptoms and activity 6 months after MR (P = 0.001 for all three scores). There were no significant differences between the two groups for the three parameters

at 6 months (Table 4). However, the increase in function (from 306.98 to 436.18), measured over 6 months, was significantly (P = 0.001) larger in patients with bone bruise than in those without (from 341.19 to 415.00). Patients with bone bruise also had significantly (P = 0.039) more decrease of symptoms (from 213.81 to 350.86) measured over 6 months than those without bone bruise (from 234.53 to 328.14) (Table 4).
The improvement in activity, measured over 6 months, was not significantly different between the two groups.
The aforementioned relatively poor function at the time of MR and subsequent improvement 6 months later, as well as the decrease in symptoms, in patients with bone bruise were associated with the presence of partial MCL tears. The above-mentioned significant differences existed between two subgroups of patients with MCL ruptures: patients with (17 patients) and without bone bruises (26 patients). There were no significant differences in function and symptoms without MCL abnormalities at the time of MR or in improvement in function or symptoms over 6 months between 201 patients without and 26 patients with bone bruise.

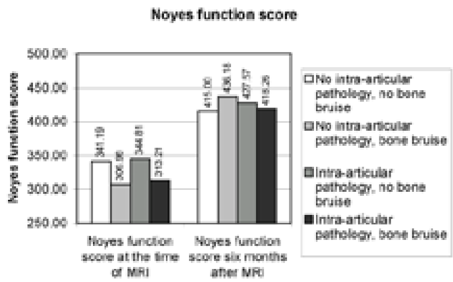

Fig. 1 Noyes function score at the time of MRI and six months later.

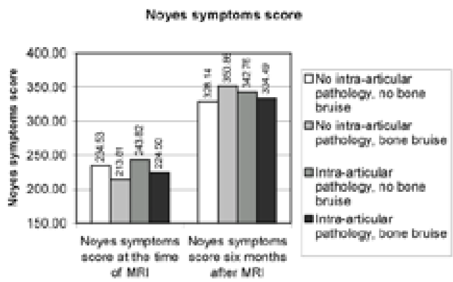

Fig. 2 Noyes symptoms score at the time of MRI and six

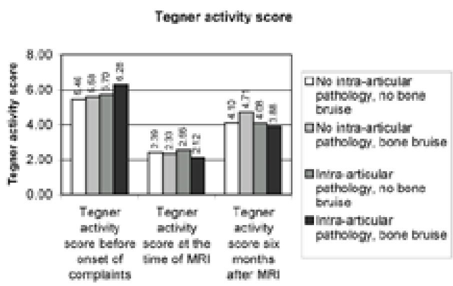

Fig. 3 Tegner activity scale before onset of complaints, at the time of MRI and six months later.

Figure 4. 4a-c Coronal and sagittal T2-weighted (respectively 2100/80 and 2350/80) image and sagittal frequency-selective fat suppressed T1-weighted (70/13; flip angle 45°) image of bone bruise in lateral femoral condyle and lateral tibial plateau in a 26 year old patient 2 months after sports injury. Arthroscopy showed a medial meniscal tear and partial ACL rupture.

Because of the small number of LCL ruptures, the difference in incidence of this injury between patients with and without bone bruise had no significant effect on level of function, symptoms and activity of both groups.

Initially (at the time of MR), there were no significant differences in symptoms, function and activity between patients that underwent arthroscopy and those that did not. Patients whom underwent arthroscopy had, compared to those that did not have arthroscopy, significantly more symptoms (Noyes symptoms 344.8 versus 321.6, P = 0.036) 6 months after MR. There were no differences in function and activity. Arthroscopy probably has no impact on the reported differences between the patients with and without bone bruise, since the fraction of arthroscopies in both groups is not significantly different (60% [26 patients] in patients with bone bruise and 55% [125 patients] in patients without bone bruise).

6.4.3. Univariate variance analysis

The presence of bone bruise was in the univariate variance analysis the only variable that had a statistically significant effect on function (P = 0.001) at the time of MR. Intra- and peri-articular pathology had no significant effect on function. Both bone bruise and the presence of MCL injuries were the variables with significant effect on symptoms at the time of MR (both P = 0.004). Intra- and peri-articular pathology had no significant effect on symptoms. Bone bruise and intra- and peri-articular pathology had no significant effect on the level of activity at the time of MR. The presence of bone bruise had no significant effect on the function, symptoms and activity 6 months after MR.

6.5. Radiographically occult fractures

Four of the five occult fractures were located in the lateral femoral condyle, the fifth in the medial tibial plateau. Two occult fractures in the lateral femoral condyle were accompanied by bone bruise in the lateral tibial plateau. Two patients had concomitant intra-articular pathology. Initial mean function score (318.0) was similar to that of patients with bone bruise. Initial mean symptoms score (280.0) was somewhat higher than in patients with bone bruise. All patients had improved considerably after 6 months (function and symptoms scores respectively 474.0 and 380.0). The same trend was visible in the Tegner activity score. Tegner activity score before onset of complaints was 6.6, decreased to 3.2 at the time of MR and increased again to 5.2 6 months later.

6.6. Discussion

The prevalence of bone bruise in our population (124 out of 664 patients [18.7%]) is lower than that reported by others [2, 5, 6, 10, 15]. A possible explanation for this difference could be the used MR sequence. Our sequence was tailored towards addressing the issue of internal derangement and related disorders including bone bruise in a general population in a time-effective way. We therefore did not use a dedicated sequence such as Short Tau Inversion Recovery (STIR) to detect bone bruise [7, 16]. It is therefore likely that we missed small bone bruises that otherwise would have been diagnosed. Another explanation for the relative low prevalence of bone bruises in patients with intra-articular pathology may be that our patients had at least 4 weeks of knee complaints, whereas only acute patients were included in other studies [5, 6, 10, 15]. In our study population, 64% had a history of trauma prior to the start of their knee complaints. A history of trauma was significantly more common (85%) in patients with bone bruise than in patients without bone bruise (59%). This confirms the relationship between trauma and bone bruise, also in our population without acute trauma.

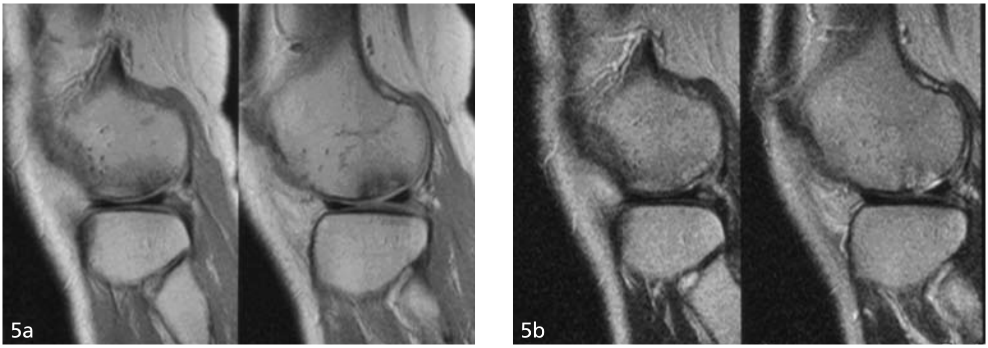

Figure 5 a, b Sagittal PD-weighted (2350/20) and sagittal T2-weighted (2350/80) image of subchondral fracture in the lateral femoral condyle, in a 32 year old female patient after trauma. Note the subchondral hypointense area of low signal intensity on the PD-weighted image, representing impacted cancelous bone. MR imaging showed no concomitant intra-articular pathology.

As did others, we found a predominance of bone bruises in the lateral femoral condyle and lateral tibial plateau [5, 6, 8-10, 15, 19]. This can be explained by the usual mechanism of injury, ie anterior subluxation of the lateral tibial plateau relative to the lateral femoral condyle and valgus stress. The significant correlation of multiplicity of bone bruises in a single patient with intra-articular pathology confirms that severity of trauma determines, in addition to trauma mechanism, the pattern of bone bruises.

Presence of bone bruise, on the other hand, is no predictor for the presence of intra-articular pathology. Prevalence of bone bruise is not significantly different between patients with (21%) and those without (16%) intra-articular pathology.

A tear of the medial meniscus is the most common injury, but is not associated with bone bruise. As did others [4-9, 17] we found, in patients with bone bruise, a higher incidence of less common injuries, ie tears in anterior cruciate ligament, collateral ligaments and lateral meniscus (Fig. 4; Table 2).

Presence of bone bruise is associated with a higher level of presenting symptoms. In the univariate variance analysis, in which all 664 patients are taken as a whole, without dividing them into subgroups, bone bruise is the only MR abnormality that has a significant effect on function at the time of presentation. Bone bruise and medial collateral ligament tear are the only parameters that have a significant effect on symptoms at the time of presentation. Thus, bone bruise and MCL tear have more impact on function and symptoms at the time of MR than intra-articular pathology such as (medial) meniscal tears. Bone bruise does not have an effect on function, symptoms and activity at 6 months. These results of the univariate variance analysis are in accordance with the detailed analysis in patients with and without intra-articular pathology.

Function (Noyes function score, Table 4, Fig. 1) is, both in patients with and without intra-articular knee pathology, at the time of MR significantly lower in patients with bone bruise than in patients without bone bruise. The decrease in activity at the time of MR (Tegner activity score, Table 4, Fig. 3) is significantly larger when patients with intra-articular pathology also have bone bruises.

During the 6 months follow-up time, significant differences are observed within the category of patients without intra-articular pathology. The increase in function and decrease of symptoms in patients with bone bruise is significantly larger than in patients without bone bruise.

At 6 months, all four groups (with or without intraarticular pathology, with or without bone bruise) display significant improvement in all three clinical parameters (function, symptoms and activity). At 6 months, the clinical differences between all four groups have disappeared. This is in accordance with the aforementioned univariate variance analysis. Wright et al. reported similar results in a retrospective study on 12 patients [18]. A recent study of Davies et al. showed that in 30 patients, all but one reported some degree of pain 12-14 weeks post-injury. In all patients, bone bruises were still present on repeat MRI [20]. No follow-up beyond this 3-month period was reported. Because of this shorter follow-up period, a direct comparison with our study regarding clinical improvement is not possible.

In the category of patients without intra-articular pathology, the clinical differences between patients with and without bone bruise are only significant in the presence of medial collateral ligament ruptures. From a clinical perspective, therefore, bone bruise and medial collateral ligament tear act as one unit.

Patients with radiographically occult fractures (Fig. 5) have impaired function and symptoms at the time of MR comparable to that of patients with bone bruise.

Six months later, these patients have improved considerably without sequelae.

The choice to follow usual care has resulted in two limitations of this study. The participation of six radiologists has introduced differences between observers that we have not measured. We feel that the large sample size and the similarity to usual practice does not impair the clinical conclusions of this study. The second limitation is the use of an MR imaging protocol tailored towards detecting intra-articular pathology. Although we used a fat-suppressed GE sequence that is sensitive to susceptibility changes, we did not use the STIR sequence. It is likely that we missed small bone bruises. It is therefore possible that the clinical relevance at the time ofMRimaging is smaller when small bone bruises are included that are below the threshold of multiplanar SE and GE imaging. It is not likely that the inclusion of these small bone bruises will have an impact on the conclusion that no clinical sequelae are detectable at 6 months.

In conclusion, we found, using a general imaging protocol, that bone bruise in combination with medial collateral ligament tear is an important cause of clinical impairment in patients with sub-acute or chronic knee complaints. It has, initially, a higher impact on clinical parameters than articular pathology, including meniscal tears. Because of the fast improvement of function, symptoms and level of activity in 6 months time prognosis is good and bone bruise has no impact on clinical parameters later on.

6.7. References

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6.8. Appendix

Noyes assessment of function

Activity	Scale	Points
Walking	Normal, unlimited	50
	Some limitations	40
	Only 1 km possible on even surface	30
	Less than 500 m possible	20
	Less than 100 m possible	0
Stairs	Normal, unlimited	50
	Some limitations	40
	Only 21-30 steps possible	30
	Only 11-20 steps possible	20
	Less than 10 steps possible	0
Squatting/kneeling	Normal, unlimited	50
	Some limitations	40
	Only 6-10 possible	30
	Only 0-5 possible	20
	Impossible	0
Straight running	Fully competitive	100
	Some limitations, guarding	80
	Half-speed, definite limitations	70
	Less than 200 m	60
	Not able	50
Sprinting	Fully competitive	100
	Some limitations	80
	Half-speed, definite limitations	70
	Only a couple of times in short time period	60
	Not able	50
Jumping	Fully competitive	100
	Some limitations	80
	Half-speed, definite limitations	70
	Limitations in every sport	60
	Not able	50
Twisting/cutting	Fully competitive	100
	Some limitations	80
	Definite limitations	70
	Limitations in every sport	60
	Not able	50

Noyes assessment of symptoms

Symptom	Scale	Points
Pain	None	100
	Able to do moderate work/sports; pain with strenuous work/sports	80
	Able to do light work/sports; pain with moderate work/sports	60
	Able to do activities of daily living (ADL); pain with light work/sports	40
	Moderate pain (frequent, limiting) with ADL	20
	Severe pain (constant, not relieved) with ADL	0
Swelling	None	100
	Able to do moderate work/sports; swelling with strenuous work/sports	80
	Able to do light work/sports; swelling with moderate work/sports	60
	Able to do activities of daily living (ADL); swelling with light work/sports	40
	Moderate swelling (frequent, limiting) with ADL	20
	Severe swelling (constant, not relieved) with ADL	0
Instability/giving way	None	100
	Able to do moderate work/sports; instability with strenuous work/sports	80
	Able to do light work/sports; instability with moderate work/sports	60
	Able to do activities of daily living (ADL); instability with light work/sports	40
	Moderate instability (frequent, limiting) with ADL	20
	Severe instability (constant, not relieved) with ADL	0
Locking	No locking and no catching sensation	100
	Less than monthly catching sensation but no locking	80
	More than once a month catching sensation but less than monthly locking	60
	Monthly locking	40
	Weekly locking	20
	Daily locking	0

Tegner Activity Score

Activity		Points
Competitive sports		10
	Soccer, national and international elite	
Competitive sports		9
	Soccer, lower divisions	
	Ice hockey	
	Wrestling	
	Gymnastics	
Competitive sports		8
	Bandy	
	Squash or badminton	
	Athletics (jumping, etc.)	
	Downhill skiing	
Competitive sports		7
	Tennis	
	Athletics (running)	
	Motorcross, speedway	
	Handball	
	Basketball	
Recreational sports		
	Soccer	
	Bandy and Ice hockey	
	Squash	
	Athletics (jumping)	
	Cross-country, both recreational and competitive	
Recreational sports		6
	Tennis and badminton	
	Handball	
	Basketball	
	Downhill skiing	
	Jogging, at least five times per week	
Work		5
	Heavy labor (e.g., building, forestry)	
Competitive sports		
	Cycling	
	Cross-country skiing	
Recreational sports		
	Jogging on uneven ground at least twice weekly	
Work		4
	Moderately heavy labor (e.g., truck driving, heavy domestic work)	
Recreational sports		
	Cycling	
	Cross-country skiing	
	Jogging on even ground at least twice weekly	
Work		3
	Light labor (e.g., nursing)	
Competitive and recreational sports		
	Swimming	
Walking in forest possible		
Work		2
	Light labor	
Walking on uneven ground possible but impossible to walk in forest		
Work		1
	Sedentary work	
Walking on even ground possible		
Sick leave or disability pension because of knee problems		0