MRI Follow-Up of Posttraumatic Bone Bruises of the Knee in General Practice

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OBJECTIVE. Our purpose was to study the natural course of bone bruises in posttraumatic knees and to describe possible determinants of this course.

SUBJECTS AND METHODS. Prospective MRI follow-up data were gathered for patients with bone bruises after sustained knee trauma. Follow-up ceased when the bone bruise could no longer be discerned or after 1 year of follow-up. For each patient we studied the relationships between time to healing of all bone bruises and the explanatory variables age, sex, obesity, workload, sports load, number of bone bruises, osteoarthritis, and concomitant knee lesions using survival analyses. We also investigated the relationships between resolution of individual bone bruises and lesion type, size and location, and the explanatory variables at 6 months and at 12 months separately, using logistic regression analyses for repeated measurements and generalized estimating equations.

RESULTS. In 80 patients, 157 bone bruises were found. The estimated median healing time was 42.1 weeks. Healing was prolonged in patients having a higher number of bone bruises and in the presence of osteoarthritis. Resolution of individual bone bruises was prolonged in the presence of osteoarthritis and greater age. Reticular lesions were less likely to be present after 6 months than other bone bruise types. None of the remaining tested variables had prognostic value.

CONCLUSION. Median healing time of bone bruises is 42.1 weeks. Prognosis is particularly influenced by the presence of osteoarthritis. Age, type of bone bruise, and number of bruises also have prognostic value.

Keywords: bone bruise, determinants, knee, natural history, trauma

DOI:10.2214/AJR.07.2276

Received November 14, 2006; accepted after revision March 22, 2007.

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AJR 2007; 189:556–562

0361–803X/07/1893–556

Since the introduction of MRI, many reports have described a new diagnosis: occult bone injury or occult intraosseous fracture [1–3]. These lesions are called "occult" because no abnormalities are seen on conventional radiographs, and in direct observation (arthroscopy) they are hidden by the overlying cartilage. These lesions, later also referred to as "bone bruises," are presumably the result of microfracture of the medullar trabeculae.

Mink and Deutsch [2] suggested that the bone bruise is a benign disorder, but later reports concluded that a bone bruise is not entirely benign [4] and is associated with increased disability in patients with anterior cruciate ligament ruptures [5].

A recent systematic review showed that, in general, a healing response to bone bruises was often encountered and that bone bruise type appeared to have prognostic value [6]. However, comparison of the individual studies in that review was difficult because of differences in the time interval between the trauma and the initial MRI, in the techniques used to detect bone lesions, in classification systems, in follow-up periods, and in treatment protocols. Most studies supply no information on initial lesion size or on the relation between concomitant lesions and bone bruises. In our opinion, all these factors might influence the presence and identification of bone lesions or might have prognostic value. The natural course of bone bruises and possible determinants thereof thus remain unclear.

The aim of this study was to describe the natural course of bone bruises using a structured MRI follow-up and to describe possible prognostic factors for the natural course.

Subjects and Methods

Patients

Our study was part of a prospective observational cohort study of 1,068 patients with new knee complaints who were in primary care (the HONEUR study) [7]. The design of the general cohort is presented in detail elsewhere [7]. The study was approved by the institutional review board of the Erasmus MC and the Medical Centre Rijnmond-Zuid, and written informed consent was obtained from each patient.

In this study, we included consecutive patients with posttraumatic knee complaints who were seeking help from their general practitioner. Patients were eligible if they had sustained an acute trauma of the knee less than 5 weeks before consultation and were 18–65 years old. We excluded patients with MRI contraindications, those with severe trauma for which immediate hospital referral was necessary, and those referred for conventional radiography showing sustained fracture. A total of 47 general practitioners participated in this study, and a total of 134 patients were included.

MRI

MRI was performed on a Signa Horizon LX 1T scanner (GE Healthcare). The following MR sequences were acquired: sagittal T1-weighted fast spin-echo (TR/TE, 575/minimum full; section thickness, 3 mm; field of view, 180 × 135 mm; matrix, 384 × 224), sagittal intermediate-weighted (3,600/minimum full) and T2-weighted (3,600/102) fast spin-echo (section thickness, 3 mm; field of view, 180 × 135 mm; matrix, 512 × 224), coronal gradient-echo T2*-weighted (325/minimum full; flip angle, 30°; section thickness, 3 mm; field of view, 180 × 135 mm; matrix, 256 × 192), coronal T2-weighted fat-suppressed (12/3,700 with fat saturation; section thickness, 3 mm; field of view, 180 × 135 mm; matrix, 385 × 224), and axial intermediate-weighted fast spin-echo (3,500/20; section thickness, 3 mm; field of view, 170 × 127.5 mm; matrix, 320 × 256) sequences. The presence of bone bruises was assessed and classified on the coronal T2-weighted fat-suppressed images.

Follow-Up Measurements

A total of 157 bone bruises in the femur and tibia were identified in 80 patients. These patients were asked to participate in the follow-up study consisting of repeat MRI at approximately 3 weeks, 10 weeks, 6 months, and 1 year after the initial MRI. Follow-up was considered complete when the bone bruise could no longer be discerned or after 1 year of follow-up. For follow-up imaging, only the coronal T2-weighted fat-suppressed sequence was used, applying the same parameters.

Assessment of MRI and Definitions

Two radiologists independently evaluated the MR images without knowledge of the physical examination. In case of disagreement, consensus was reached.

Bone bruise severity at baseline was classified according to the percentage of bone volume involved: none, minimal, less than 25%, 25–50%, 50–75%, and greater than 75%. This was done for each possible site of bone bruise (i.e., lateral or medial femur, lateral or medial tibia). At follow-up, bone bruise was classified as present or absent.

Bone bruise was identified as an area of abnormally high signal intensity in the subchondral bone or marrow on the T2-weighted fat-suppressed images. Bone bruise was classified according to the Vellet classification [8]: reticular lesions, geographic lesions, and other lesions (i.e., impaction, osteochondral and subcortical fractures) (see Appendix 1).

Resolution of bone bruise was defined as the resolution of an individual bone bruise. Healing of bone bruise was defined as resolution of all bone bruises in a patient at follow-up.

Menisci were classified as intact or torn. Cruciate ligaments and collateral ligaments were dichotomized as normal or (partially or totally) ruptured. Osteoarthritis of the knee was defined as absent (i.e., no abnormalities or minimal osteophytes of dubious significance at MRI) or present (i.e., osteophytes or joint space narrowing, possibly associated with sclerosis of the subchondral bone at MRI).

Workload and sports load were assessed according to the baseline questionnaire, identifying four workload categories: no occupation, sedentary occupation (e.g., office job), occupation in which the patient had to stand nearly all day (e.g., hairdressing), and heavy physical work (e.g., construction work); and three sports load categories: no sporting activity, less than 4 hours of sporting activity per week, and 4 hours or more of sporting activity per week.

Data Analyses

Previous analyses showed that the interobserver agreement for the bone bruise volume classification (none, minimal, less than 25%, 25–50%, 50–75%, and greater than 75%) at baseline was high (intraclass correlation coefficient, 0.95–1.0) (Boks SS et al., unpublished data). In the current study, interobserver agreement was assessed for the resolution of bone bruises at each follow-up MRI examination using the kappa statistic.

The survival time to healing was estimated using a Weibull survival function [9], allowing for left and right censoring. First, we plotted the survival curve for all 80 patients and estimated the median healing time. Next, we estimated the univariate relationships between healing time and age (years), sex, obesity (body mass index > 30 kg/m^2), workload, sports load, number of bone bruises, osteoarthritis, cruciate or collateral ligament tears, and meniscal ruptures. Finally, the relative healing time for different levels of each explanatory variable, adjusted for the other explanatory variables, was estimated using a multivariate model and including all variables with a univariate p value of less than 0.10.

In addition, we investigated the relation between resolution of the 157 individual bone bruise lesions at 6 and 12 months separately and the explanatory variables. For this, we used logistic regression analyses for repeated measurements and generalized estimating equations to account for the multilevel structure of the data (lesions in patients). In these analyses, the presence of separate bone bruise lesions was used as the dependent variable. As independent variables we entered lesion-specific characteristics (i.e., type of bone bruise, location [femur vs tibia, lateral vs medial], severity [25% vs ≥ 25% of bone volume involved]), and the patient-specific characteristics previously mentioned. We estimated odds ratios (ORs) for all explanatory variables using logistic multivariate models. Explanatory variables with a univariate p value of less than 0.10 were included in the model. A p value of less than 0.05 was considered significant.

All analyses were performed using SPSS (version 11.0.1, SPSS) and SAS (version 9.1, SAS Institute) software.

Results

Table 1 gives the characteristics of the 80 patients included in this study. MRI was performed an average of 5.3 weeks after the sustained trauma (range, 2.0–11.1 weeks). The interobserver agreement for resolution of individual bone bruises was high (initial agreement on 397 of 436 scores: $\kappa = 0.82$).

Figure 1 shows follow-up was complete in 72 patients (i.e., bone bruise was absent, or the follow-up period was completed at 1 year). The eight patients with incomplete follow-up included three participants with no follow-up, three with one control MRI scan, one with two controls, and one with three control MRI scans after baseline measurements. Twenty-two participants showed a bone bruise at the 1-year follow-up; these participants had 36 bone bruises (of the 66 initial lesions in this group). The eight participants with incomplete follow-up had 13 initial lesions, of which one had disappeared. Thus, of the 157 initial lesions, 12 lesions (7.6%) were lost to follow-up and 36 lesions (22.9%) were still present after 1 year.

Healing of Bone Bruise Patients

Figure 2 shows the fraction of bone bruise patients who had not healed over time. The median healing time was 42.1 weeks for the total study population. Age, sex, obesity, workload, and sports load were not related to healing time on the patient level, nor was the presence of concomitant meniscal, cruciate ligament, or collateral ligament rupture (Table 2, all p values > 0.20). In patients with knee osteoarthritis, the healing time was

TABLE 1: Characteristics of 80 Patients with One or More Bone Bruise Lesions at Baseline MRI

Characteristic	No.	%
Sex		
Women	35	43.8
Men	45	56.3
Obesity[a]	15	18.8
Workload		
No working activities	25	31.3
Sedentary	34	42.5
Primarily standing	17	21.3
Heavy physical work	4	5.0
Sports load		
None	23	28.8
< 4 h/wk	33	41.3
≥ 4 h/wk	24	30.0
Knee lesions		
No. of bone bruises		
One	37	46.3
Two	19	23.8
Three	14	17.5
Four	10	12.5
Rupture of		
Meniscus	35	43.8
Cruciate ligament	21	26.3
Collateral ligament	33	41.3
Osteoarthritis of knee	12	15.0
Age (y)		
Mean	43.5	
Range	21.2–63.8	

[a]Body mass index > 30 kg/m^2.

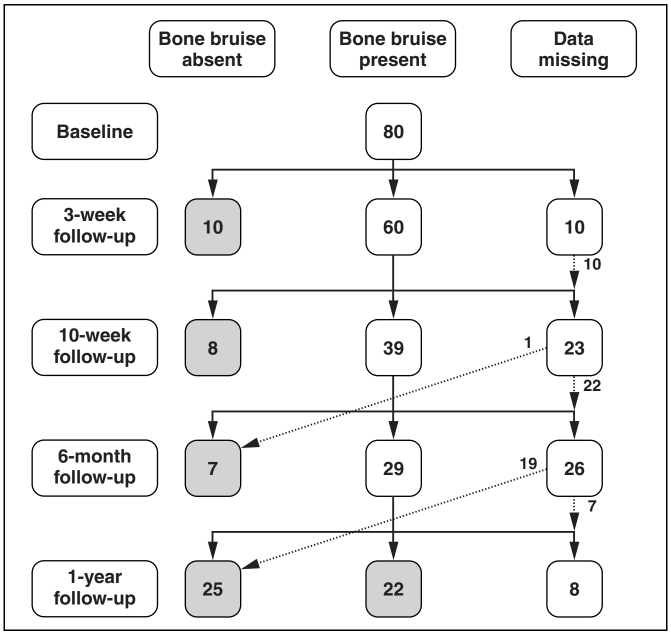

Fig. 1—Presence of bone bruise in 80 posttrauma patients until 1 year of follow-up. Gray boxes refer to patients with complete follow-up (i.e., bone bruise absent at follow-up, or 1-year follow-up completed). Numbers on dotted lines represent participants who were transferred from one category to another.

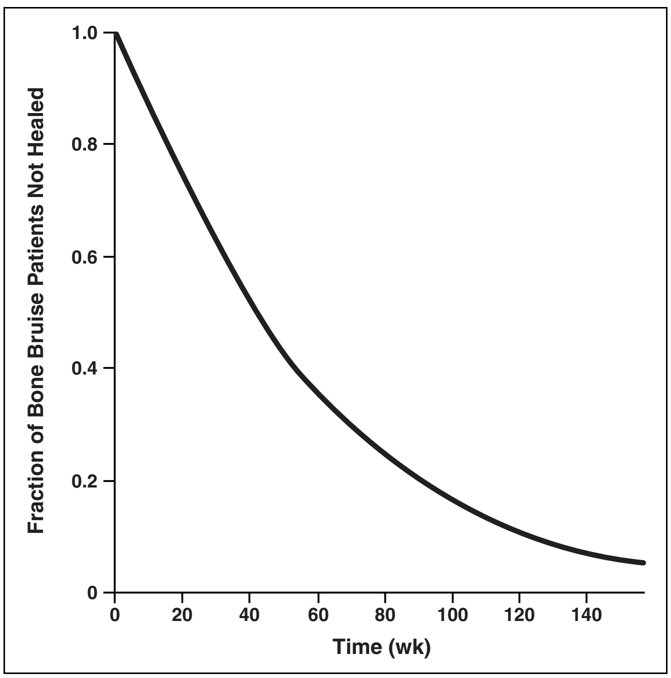

Fig. 2—Fraction of bone bruise patients not healed over time.

about twice that of patients without osteoarthritis (Table 2, multivariate analysis). The number of bone bruises prolonged the healing time by approximately one third per additional lesion. In the multivariate analyses, both osteoarthritis and the number of lesions showed a prolonged healing time, but neither was statistically significant ($p = 0.1$).

Resolution of Individual Bone Bruise Lesions

Figures 3 and 4 present examples of the gradual resolution of bone bruises over time. Of the initial 157 bone bruises, 6-month follow-up data were available in 114 lesions and 12-month follow-up data, in 145 lesions. Logistic regression analysis with bone bruises as units of analysis showed a relation between the presence of a bone bruise after 6 and 12 months and older age (adjusted OR, 1.0 [95% CI, 1.0–1.1]) (Table 3). Osteoarthritis was a clear prognostic variable for the presence of bone bruise at 6 months (adjusted OR, 3.0 [1.0–9.2]) and at 12 months (adjusted OR, 5.6 [1.9–16.9]). Reticular lesions were less likely to be present after 6 months (adjusted OR, 0.2 [0.0–1.1]) than other bone bruise types. At the 12-month follow-up, no statistically significant relationship was seen between the presence of a bone bruise and bone bruise type (Table 3). Number, location, and severity of lesions; sex; obesity; workload; sports load; and concomitant meniscal, cruciate ligament, and collateral ligament tears were not significantly related to resolution of the individual bone bruises.

TABLE 2: Relative Healing Time of Bone Bruises for Explanatory Variables (Expressed in Percentages)

Variable	% Longer Healing Time[a]		
	Univariate	p	Multivariate
Age (% per year)	1.6 (–1.0 to 4.3)	0.22	NI
Gender (female vs male)	23.9 (–35.0 to 136.3)	0.51	NI
Obesity	51.8 (–41.9 to 296.5)	0.39	NI
Workload (per increasing category)[b]	–10.3 (–29.4 to 14.0)	0.37	NI
Sports load (per increasing category)[b]	–0.6 (–35.7 to 53.7)	0.98	NI
No. of lesions (per category)[b]	56.9 (10.4–122.9)	0.01	34.6 (–5.1 to 90.9)
Meniscal rupture	47.9 (–21.9 to 180.2)	0.23	NI
Cruciate ligament rupture	17.7 (–45.2 to 152.7)	0.68	NI
Collateral ligament rupture	–30.9 (–63.3 to 30.1)	0.25	NI
Osteoarthritis of the knee	338.5 (15.9–1,558.3)	0.03	203.7 (–21.4 to 1073.9)

Note—Numbers in parentheses are 95% CIs. NI = not included in multivariate model (univariate $p > 0.10$).
[a]Refers to difference (expressed as percentage) in mean healing time between tested groups (e.g., in women, time to healing takes 23.9% longer than in men).
[b]See Table 1 for categories.

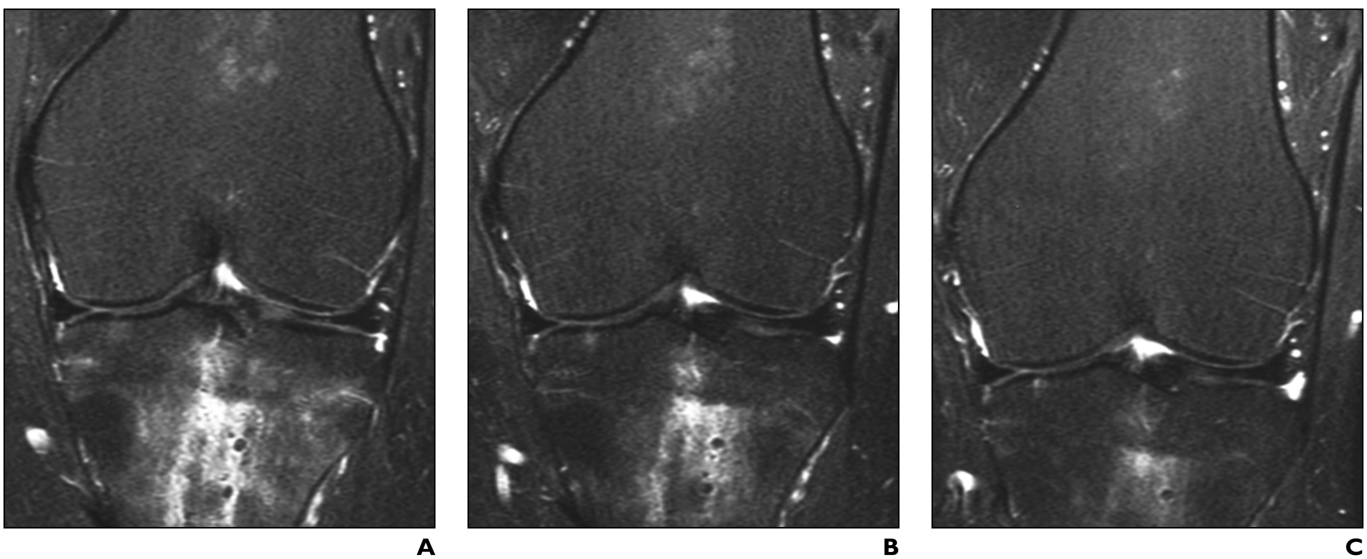

Fig. 3—57-year-old woman with gradual resolution of subcortical fracture.
A–C, Coronal T2-weighted fat-suppressed images (TR/TE, 12/3,700; fat saturation; section thickness, 3 mm; field of view, 180 × 135 mm; matrix, 385 × 224) show gradual resolution of bone bruise (subcortical fracture) over time from baseline (**A**), to 3-week follow-up (**B**), and at 9-week follow-up (**C**).

Discussion

To our knowledge, our study is the first structured prospective follow-up study of MRI-detected posttraumatic bone bruises. The median healing time of bone bruise patients was 42.1 weeks, and healing time was prolonged in the presence of osteoarthritis and a greater number of initial bone bruises. Resolution of individual bone bruises is related to the presence of osteoarthritis, age, and type of bone bruise. Concomitant knee lesions, sex, obesity, workload, sports load, location, and severity of bone bruise were not related to the natural course of bone bruise.

In the past, the time to resolution of bone bruises has been debated. An early study on this subject suggested that bone bruises resolve within 12 weeks of the acute injury [10], whereas more recent studies have shown that bone bruises can persist much longer [4, 11–13]. In the available follow-up studies on bone bruises, follow-up is nearly always restricted to one MRI examination. Only Bretlau et al. [11] used two follow-up examinations, showing that after a longer follow-up further healing is possible. Comparison of the results of the studies is difficult because of differences in follow-up periods and the techniques used to detect bone lesions. None of the studies used a structured follow-up [6].

We realize that the median healing time, as calculated in our study, is not an exact measure. The time between the follow-up scans was not uniform. The rationale for performing follow-up scanning at approximately 3 weeks, 10 weeks, 6 months, and 1 year after the initial

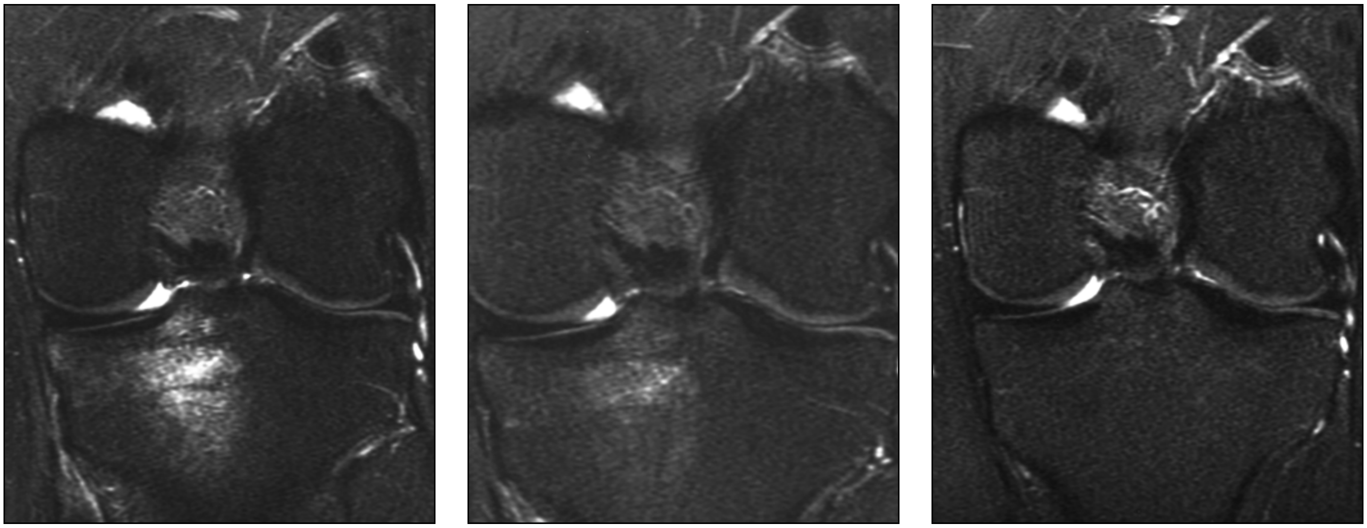

Fig. 4—31-year-old man with fast resolution of bone bruise, reticular lesion type.
A–C, Coronal T2-weighted fat-suppressed images (TR/TE, 12/3,700; fat saturation; section thickness, 3 mm; field of view, 180 × 135 mm; matrix, 385 × 224) show fast resolution of bone bruise from baseline (**A**), to 3-week follow-up (**B**), and at 9-week follow-up (**C**).

scanning was that this schedule was expected to enable an accurate survival analysis, taking into account both the fast-resolving lesions and the more slowly resolving lesions. In addition, we thought it was important to keep patient compliance as high as possible. Had we also performed additional scanning at 9 months, the calculated median healing time might have been even more precise; however, because only six patients (seven lesions) in our data set had bruises that resolved unequivocally during this period, additional follow-up scanning would probably not have influenced the calculated healing time substantially. Censoring may have caused some inaccuracy in the estimated healing time but is not likely to have had a major effect.

Healing was defined as the total absence of bone bruise lesions in a patient at follow-up. Small rest lesions, which in daily practice might be ignored or overlooked, were also counted. We decided not to exclude these small, insignificant-looking lesions (exclusion would result in a shorter healing time) because we were interested in the complete healing of patients.

We hypothesized that the tested independent variables might be related to the natural healing of a bone bruise. However, another potentially important variable—treatment protocol—was not tested. The main reason for this was that we followed an observational study design. The 47 general practitioners who participated in our study used their own treatment strategies, making it difficult to compare patients. The general practitioners were not informed about the MRI results, and we did not want to interfere with their treatment strategies. Treatment choice is probably influenced by the severity of the complaints (reverse causation). Reliable information on the effect of treatment (e.g., load reduction) can be obtained only by means of an interventional study.

We performed our survival analyses on the patient level. Similar survival analyses on the resolution of individual bone bruises showed (not surprisingly) a smaller median time to resolution (33 weeks); however, we think this latter measure is not clinically meaningful. Moreover, this survival analysis does not take into account the correlation among several lesions in one knee.

Baseline severity of a bone bruise appeared to have no significant prognostic value. We realize that our bone bruise volume measurements are only an approximation of the true bone bruise volume. Others have described a computer-assisted method for quantification of bone marrow edema [14]. Although it is a more exact quantification technique with a low intraobserver variation, this method has proven to be too time-consuming for clinical use [14]. In our study, we classified the severity of bone bruise according to the percentage of bone volume involved. This proved to be a quick method with good reproducibility (κ = 0.95–1.00) and can be used to compare bone bruise severity among individual patients. For statistical purposes (small groups in the more severe categories), we dichotomized bone bruise severity into light (< 25% volume) or severe (≥ 25%) involvement. The most severe category (> 75% volume involvement) seems to have had a longer healing time, but this could not be tested reliably because of the small groups.

Our results show that bone bruise healing is mainly related to the presence of osteoarthritis. Previous studies have described a relation between osteoarthritis and the bone marrow edema pattern [15–19]. In our earlier study of determinants of bone bruise (Boks SS et al., unpublished data), we showed that the prevalence of bone bruises is higher in osteoarthritic patients (multivariate analyses: OR, 3.3 [0.8–14.1]). In osteoarthritic patients, the bone bruises might have been preexisting and may have worsened as a result of trauma. On the other hand, bone bruises may persist longer because of reduced cartilage thickness (and therefore reduced absorption of compressive forces) or altered subchondral bone quality [20]. The design of our study did not allow us to prove causality.

We found that all the lesions in one patient do not heal at exactly the same speed. Therefore, an influence by the number of bone bruises on healing time was expected; the higher the number, the more likely that there will be one slowly resolving lesion.

We found that the univariate effect of osteoarthritis and the number of bone bruises on time to healing was lost in multivariate analyses. This suggests that there was a confounding effect. Post hoc analyses showed that there also seemed

TABLE 3: Prediction of Presence (Nonresolution) of Individual Bone Bruises (n = 157) at 6 and 12 Months and Relationship with Baseline Variables

	At 6 Months (n = 114)				At 12 Months (n = 145)			
Variable	No.	Crude OR (95% CI)	p	Adjusted OR (95% CI)	No.	Crude OR (95% CI)	p	Adjusted OR (95% CI)
Age (y)		1.1 (1.0–1.1)	0.01	1.0 (1.0–1.1)		1.1 (1.0–1.1)	0.009	1.1 (1.0–1.1)
Sex				NI				NI
Men[a]	64	1.0			82	1.0		
Women	50	1.7 (0.7–4.1)	0.24		63	1.2 (0.5–3.1)	0.69	
Obesity[b]	26	1.1 (0.4–3.6)	0.84	NI	32	1.7 (0.6–5.4)	0.33	NI
Workload				NI				NI
No working activities[a]	34	1.0			41	1.0		
Sedentary	55	1.4 (0.5–3.8)	0.54		66	1.3 (0.5–3.8)	0.61	
Primarily standing	19	1.0 (0.3–3.1)	0.96		31	0.8 (0.2–3.2)	0.73	
Heavy physical work	6	0.5 (0.0–6.6)	0.60		7	0.9 (0.1–10.8)	0.96	
Sports load				NI				NI
None[a]	35	1.0			42	1.0		
< 4 h/wk	42	1.7 (0.6–5.3)	0.34		59	1.2 (0.4–3.9)	0.76	
≥ 4 h/wk	37	0.8 (0.2–2.6)	0.65		44	0.7 (0.2–2.5)	0.53	
Knee lesions								
Meniscus[c]	61	1.9 (0.8–4.7)	0.16	NI	79	1.7 (0.7–4.5)	0.25	NI
Cruciate ligament[c]	42	0.4 (0.2–1.2)	0.11	NI	50	0.6 (0.2–1.7)	0.33	NI
Collateral ligament[a,c]	48	1.0 (0.4–2.4)	0.94	NI	61	1.1 (0.4–2.8)	0.84	NI
Osteoarthritis	30	4.3 (1.6–11.3)	0.003	3.0 (1.0–9.2)	31	8.5 (3.4–21.6)	< 0.001	5.6 (1.9–16.9)
Bone bruise								
No. of lesions		1.2 (0.8–1.8)	0.36	NI		1.4 (0.9–2.1)	0.14	NI
Type								NI
Geographic	62	0.7 (0.2–2.7)	0.58	0.5 (0.1–2.0)	80	1.1 (0.4–3.1)	0.89	
Reticular	42	0.2 (0.0–1.2)	0.09	0.2 (0.0–1.1)	53	0.5 (0.1–1.5)	0.20	
Other[a,d]	10	1.0		1.0	12	1.0		
Location				NI				
Femur[a]	56	1.0			67	1.0		1.0
Tibia	58	0.9 (0.5–1.6)	0.69		78	0.5 (0.2–1.1)	0.09	0.4 (0.2–0.9)
Location				NI				NI
Lateral[a]	51	1.0			67	1.0		
Medial	63	0.9 (0.5–1.7)	0.74		78	0.9 (0.4–2.0)	0.87	
Severity				NI				NI
< 25%[a]	86	1.0			109	1.0		
≥ 25%	28	1.6 (0.6–4.5)	0.33		36	1.1 (0.5–2.7)	0.78	

Note—Numbers in parentheses are 95% CIs. OR = odds ratio for presence (i.e., nonresolution) of bone bruise lesion, crude OR applies to univariate analyses, adjusted OR applies to multivariate analyses with variables having univariate $p < 0.10$. NI = not included in multivariate model (univariate $p > 0.10$).
[a]Reference factor (OR = 1).
[b]Body mass index > 30 kg/m^2.
[c]Rupture vs no rupture.
[d]Included at 6 months, seven impaction, two subcortical, and one osteochondral fractures; and at 12 months, nine impaction, two subcortical, and one osteochondral fractures.

to be effect modification (or interaction); in participants with osteoarthritis, the effect of the number of lesions was larger than in participants without osteoarthritis. The interpretation of these post hoc analyses is hampered because of small numbers in the different groups.

Healing time was slightly prolonged in a patient with an associated cruciate ligament or meniscal injury, but the difference was not statistically significant. This finding is in agreement with a previous study by Davies et al. [4].

Bone bruise type appeared to have prognostic value (OR at the 6-month follow-up, 0.2 for reticular lesions). This agrees with the results of a systematic review on the follow-up of MRI-detected posttraumatic bone bruises [6]. In that review, a consistently good prognosis for reticular lesions was described, whereas the reported prognosis for geographic lesions differed among studies. At the 12-month follow-up, reticular lesions again showed smaller ORs, but the difference between lesion types was not statistically significant.

For daily practice, it is important to recognize that bone bruises take a relatively long time to dissipate (longer than suggested in the earliest studies on this subject). Prognosis is mainly influenced by the presence of osteoarthritis, but the type of bone bruise and age also appear to have prognostic value.

Future studies must establish whether the presence of a bone bruise is related to clinical symptoms such as pain. Moreover, the long-term prognosis of these lesions should be determined, with particular focus on the overlying cartilage. Histopathologic studies have reported a profound effect of trauma on cartilage metabolism [21–23]. The chondral surface could undergo chondrolysis and death proportionate to an impactive force and its distribution [8]; this may lead to premature degeneration even in the absence of other substantial soft-tissue trauma. When the presence of a bone bruise is related to clinical symptoms or a worse long-term prognosis, studies on the effect of different treatment strategies seem appropriate.

In conclusion, the estimated median healing time in our patients with posttraumatic bone bruises in the knee was 42.1 weeks. Prognosis is particularly influenced by the presence of osteoarthritis, but age, type of bone bruise, and number of bone bruises also have prognostic value.

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APPENDIX 1: Types of Bone Bruise According to the Vellet Classification [8]

Reticular lesion	Serpiginous region of increased T2-weighted fat-suppressed signal distant from subchondral bone plate
Geographic lesion	Discrete confluent focus of high signal contiguous to subchondral plate
Subcortical fracture	Discrete linear zone of increased T2-weighted fat-suppressed signal < 2 mm wide with sharp zone of transition to adjacent marrow fat
Impaction fracture	Depression of articular surface in conjunction with a geographic-type lesion
Osteochondral fracture	Geographic lesion (as defined above) with a discrete interface marginating lesion from surrounding trabecular bone and communicating with joint space