Original Research

Classification of Bone Bruises in Pediatric Patients With Anterior Cruciate Ligament Injuries

Hong-De Wang,* MD, Jiahao Zhang,* MD, Yuwan Li,* MD, Zong Li,* MD, Wenqiang Yan,* MD, and Yingfang Ao,*† MD

Investigation performed at Peking University Third Hospital, Peking University, Beijing, China

Background: Bone bruises are frequently found on magnetic resonance imaging (MRI) after an anterior cruciate ligament (ACL) tear in pediatric patients.

Purpose: To establish a classification system for different bone bruise patterns to estimate the severity of a knee injury in pediatric patients with ACL tears.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: A medical database was retrospectively reviewed to identify all cases of primary ACL tears in patients who were aged ≤17 years at the time of the injury and underwent MRI at our institution within 4 weeks of the injury between January 2011 and December 2020. A total of 188 patients were identified (67 male, 121 female; mean age, 15.1 ± 1.4 years). Bone bruises were classified according to their depth and location on MRI in the sagittal and coronal planes.

Results: The new classification system identified 3 grades of depth: grade I, the bone bruise was located within the epiphysis but did not reach the epiphyseal plate (n = 54 [35.3%]); grade II, the bone bruise was within the epiphysis that reached the epiphyseal plate (n = 55 [35.9%]); and grade III, the bone bruise was in both the epiphysis and metaphysis (n = 44 [28.8%]). The bone bruise location was classified into 4 types: type a, the deepest bone bruise area was in the lateral tibial plateau (n = 66 [43.1%]); type b, the deepest bone bruise area was in the lateral femoral condyle, commonly occurring in the lateral one-third to two-thirds of the lateral femoral condyle (n = 22 [14.4%]); type c, the bone bruise area had a similar depth in both the lateral femoral condyle and lateral tibial plateau (n = 54 [35.3%]); and type d, the bone bruise area was in the lateral tibial plateau and lateral femoral condyle and extended to the fibular head (n = 11 [7.2%]). The prevalence of collateral ligament injuries increased from grade I to III. All patients with grade III type c bone bruises had meniscal lesions.

Conclusion: This new classification system provides a basis for estimating associated lesions of the knee before surgery.

Keywords: anterior cruciate ligament (ACL); bone bruise; pediatric patient; classification; magnetic resonance imaging (MRI)

An anterior cruciate ligament (ACL) injury is one of the most common and serious injuries that affects the young and physically active population.[7,12,26] A bone bruise is frequently found on magnetic resonance imaging (MRI) of pediatric patients with ACL injuries.[6,22,33] A bone bruise is associated with osseous edema or trabecular microfracture caused by a collision between the tibia and femur.[30] Furthermore, the degree of bone bruising may be related to the amount of energy impact on the knee during an injury.[15]

Numerous studies have investigated the presence and distribution pattern of bone bruises in adults with ACL injuries,[32,36,39] but little is known about bone bruises in pediatric patients. To date, several radiological studies have investigated bone bruises and ACL injuries in pediatric patients.[20,21,23] Bordoni et al[3] reported a higher prevalence and similar distribution pattern of bone bruises and cartilage and meniscal lesions in pediatric patients with

†Address correspondence to Yingfang Ao, MD, Department of Sports Medicine, Beijing Key Laboratory of Sports Injuries, Institute of Sports Medicine, Peking University Third Hospital, Peking University, 49 North Garden Road, Haidian District, Beijing, 100191, China (email: aoyingfang@163.com).

*Department of Sports Medicine, Beijing Key Laboratory of Sports Injuries, Institute of Sports Medicine, Peking University Third Hospital, Peking University, Beijing, China.

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ACL injuries compared with adults. However, the distribution pattern was summarized as the location of bone bruises in all included patients instead of classifying the location of the bone bruise in each patient. Thus, this previous study was unable to estimate the severity of the knee injury in pediatric patients in accordance with the location of the bone bruise on MRI.[4,18,19] Possibly because of the shock-absorbing function of the physis in the pediatric population, fewer bone bruises cross the physis and extend into the metaphysis in pediatric patients (tibial: 25%; femoral: 4%) compared with adults (tibial: 85%; femoral: 42%).[28] The energy from the injury would be absorbed in the physis, minimizing the energy that reaches the metaphysis.[28] Therefore, to estimate the severity of a knee injury in pediatric patients with ACL tears, it is important to consider 2 factors of the bone bruise. The first one is the depth, which is described as whether the bone bruise crosses the physis and extends into the metaphysis. The second one is the location, which comprises the tibial-femoral side and medial-lateral side.

The purpose of this study was to document the presence, distribution pattern, and associated lesions of bone bruises in pediatric patients with complete primary ACL tears as well as to propose a new classification system for bone bruises based on their depth and location.

METHODS

Patient Selection

The protocol for this retrospective analysis was approved by our institutional ethics committee. The electronic medical database of our institution was retrospectively reviewed to identify all pediatric patients who underwent primary ACL reconstruction for complete primary ACL tears between January 2011 and December 2020. All patients were aged ≤17 years at the time of the injury and underwent MRI at our institution within 4 weeks of the injury. Patients were excluded if they had closed physes, a documented history of injuries or surgery involving the studied knee, or no available injury date and MRI data.

Diagnosis of Bone Bruises

A bone bruise was defined as a trauma-induced, geographic, nonlinear area of decreased signal intensity on T1-weighted MRI and increased signal intensity on T2-weighted MRI. All patients underwent MRI of the injured knee using our standard protocol. Scans were acquired on a 1.5-T scanner (SIGNA; GE Healthcare) with a 3.5-mm slice thickness and 512 × 512 matrix in the sagittal, coronal, and axial planes.

Classification Criteria

MRI scans were separately reviewed by 2 independent sports medicine surgeons (H.-D.W. and Y.L.) specializing in pediatric orthopaedic surgery. Disagreements were resolved through a discussion among the other authors. The bone bruises were classified according to their depth and location observed on MRI in the sagittal and coronal planes.

The depth of the bone bruise on MRI was determined based on whether it reached or crossed the epiphyseal plate of the femur and/or tibia. Grade I was defined as a bone bruise located within the epiphysis that did not reach the epiphyseal plate. The high signal intensity extended from the joint surface to the superficial or middle layer of the epiphysis. In the sagittal view, there was a triangular-shaped and spotty bone bruise area under the joint line in the femoral condyle and tibial plateau, respectively. Grade II was defined as a bone bruise within the epiphysis that reached the epiphyseal plate. The high signal intensity ran through all layers of the epiphysis but did not enter the metaphysis. In the sagittal view, there was a trapezoidal-shaped and bar-shaped bone bruise area under the joint line in the femoral condyle and tibial plateau, respectively. Grade III was defined as a bone bruise in both the epiphysis and metaphysis. The high signal intensity ran through all layers of the epiphysis and extended to the metaphysis. In the sagittal view, there was a large irregular-shaped and triangular-shaped bone bruise area under the joint line in the femoral condyle and tibial plateau, respectively.

The bone bruise location was documented as the femur, tibia, and/or fibular head and as the anterior-posterior or lateral-medial direction.[25,28] In type a, the deepest bone bruise area was in the lateral tibial plateau. In type b, the deepest bone bruise area was in the lateral femoral condyle, commonly occurring in the lateral one-third to two-thirds of the lateral femoral condyle. In type c, the bone bruise area had a similar depth in both the lateral femoral condyle and lateral tibial plateau. In type d, the bone bruise area was in the lateral tibial plateau and lateral femoral condyle and extended to the fibular head.

Associated Lesions

Associated lesions included cartilaginous injuries of the femoral condyle and tibial plateau, injuries of the medial collateral ligament (MCL) or lateral collateral ligament (LCL), and meniscal injuries. Cartilaginous and meniscal injuries were determined based on MRI and recorded intraoperative findings. The International Cartilage Regeneration & Joint Preservation Society (ICRS) system was used to evaluate the quality of cartilage injuries.[24,29] A collateral ligament injury was determined based on MRI and physical examination findings recorded in the resident admission notes. Collateral ligament injuries were documented as grade 2 or 3 tears.[25] Grade 2 tears were characterized as tearing of the ligament with only mild instability,[10,11] and grade 3 tears were defined as a complete tear with a grossly unstable knee.[9,25,27]

Statistical Analysis

Statistical analysis was performed with SPSS (Version 26; IBM). Continuous variables were reported as mean ± SD. The Kruskal-Wallis H test was used to compare associated

TABLE 1
Patient Demographics[a]

Variable	All Patients (N = 188)	Patients With Bone Bruise (n = 153)
Age, y	15.1 ± 1.4	15.2 ± 1.3
Sex		
Male	67 (35.6)	55 (35.9)
Female	121 (64.4)	98 (64.1)
Time from injury to MRI, wk	1.8 ± 1.4	1.8 ± 1.4
Laterality		
Left knee	88 (46.8)	75 (49.0)
Right knee	100 (53.2)	78 (51.0)

[a]Data are reported as n (%) or mean ± SD. MRI, magnetic resonance imaging.

TABLE 2
Bone Bruise Locations[a]

Location	n (%)
LTP + LFC	47 (30.7)
LTP + LFC + MTP	25 (16.3)
LTP + LFC + MFC	20 (13.1)
LTP + LFC + MTP + MFC	19 (12.4)
LFC	13 (8.5)
LTP	13 (8.5)
LTP + MTP	4 (2.6)
LTP + LFC + FH + MFC	3 (2.0)
LTP + LFC + FH + MTP	3 (2.0)
LTP + LFC + FH + MTP + MFC	3 (2.0)
LTP + LFC + FH	2 (1.3)
LFC + MFC	1 (0.7)
Total	153 (100.0)

[a]FH, fibular head; LFC, lateral femoral condyle; LTP, lateral tibial plateau; MFC, medial femoral condyle; MTP, medial tibial plateau.

lesions among the grades of bone bruises. The alpha level for statistical significance was set at $P < .05$.

RESULTS

Patient Demographics and Characteristics

Included in the study were 188 patients (mean age, 15.1 ± 1.4 years; 64.4% female). The prevalence of a bone bruise was 81.4% (n = 153). The characteristics of the overall sample as well as the patients with bone bruises are summarized in Table 1. The mean time from injury to MRI was 1.8 ± 1.4 weeks. Injury characteristics are presented in Table 2. The bone bruise was located on the lateral side in all 153 patients. The most common bone bruise location was the lateral tibial plateau (90.8%), followed by the lateral femoral condyle (88.9%) and the fibular head (7.2%).

Bone Bruise Classification by Depth and Location

Bone bruises as classified by depth were as follows: grade I (n = 54 [35.3%]), grade II (n = 55 [35.9%]), and grade III (n = 44 [28.8%]) (Figures 1 and 2 and Table 3). According to the location of the bone bruise between the lateral femoral condyle and lateral tibial plateau, each bone bruise was further classified into 4 types: type a (n = 66 [43.1%]), type b (n = 22 [14.4%]), type c (n = 54 [35.3%]), and type d (n = 11 [7.2%]) (Figures 1 and 2 and Table 3). None of the patients had a bone bruise of the fibular head alone.

Associated Lesions

Cartilaginous injuries were present in 22 (14.4%) patients with bone bruises (Table 4). The lesion was medial in 12 patients, lateral in 6 patients, and both medial and lateral in 4 patients. Of these 22 patients, 5 had ICRS grade 4 cartilaginous injuries with grade III bone bruises that needed to be treated. The presence of cartilaginous injuries did not significantly differ according to the grade of bone bruises ($P = .172$) or the type of bone bruises (type a: $P = .460$; type b: $P = .417$; type c: $P = .413$; type d: $P = .892$).

Collateral ligament injuries were present in 32 (20.9%) patients with bone bruises (Table 4). The injured ligament was the MCL in 27 patients, the LCL in 1 patient, and both the MCL and LCL in 4 patients. The presence of collateral ligament injuries differed significantly by bone bruise grade (grade I: n = 1 [1.9%]; grade II: n = 11 [20.0%]; grade III: n = 20 [45.5%]; $P < .001$). Among patients with each type of bone bruise, the frequency of collateral ligament injuries significantly increased from grade I to grade III (type a: $P = .034$; type b: $P = .038$; type c: $P = .001$; type d: $P = .045$).

Meniscal injuries were present in 93 (60.8%) patients with bone bruises (Table 4). The injured meniscus was medial in 35 patients, lateral in 34 patients, and both medial and lateral in 24 patients. The prevalence of meniscal injuries did not significantly differ by the grade of bone bruises ($P = .249$). Among the patients with type c bone bruises, meniscal injuries were present in 16 (53.3%) patients with a grade I bone bruise, 12 (80.0%) patients with a grade II bone bruise, and 9 (100.0%) patients with a grade III bone bruise ($P = .017$).

DISCUSSION

Based on their depth and location, the bone bruises in pediatric patients with complete primary ACL tears were

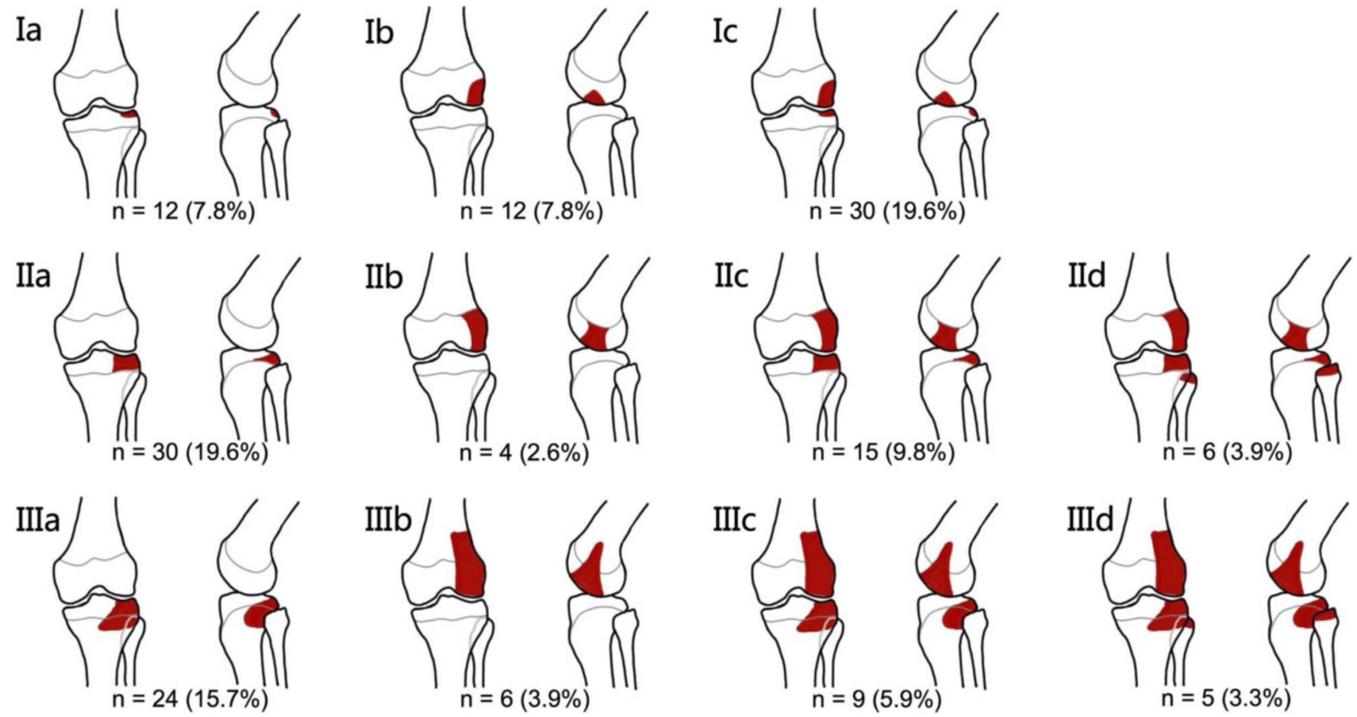

Figure 1. Illustration of the classification and frequency of bone bruises in the study patients (n = 153).

classified into 3 grades and 4 types to provide a basis for estimating the severity of the knee injury before surgery. The 2 important findings of the current study were that the frequency of collateral ligament injuries increased from grade I to grade III and that a meniscal injury was present in all patients with grade III type c bone bruises.

The injury severity can be judged by the bone bruise depth and associated lesions. A higher amount of energy leads to more injuries to bone and cartilage, resulting in an increased bone bruise depth on MRI.[15] Patients with a ruptured ACL due to a contact injury reportedly have shallower bone bruises in the medial compartment than patients with a noncontact injury because of less valgus force involved in the contact mechanism.[36] One study of 2 patients with ACL injuries with lateral tibial plateau bone bruises reported that a small amount of energy may be demonstrated by a small bone edema pattern.[37] In the pediatric population, the trabecular bone structure of the physis is almost exclusively responsible for the transmission of loads at the epiphysis from the knee joint to the metaphysis.[14] Thus, a bone bruise in skeletally immature patients with ACL ruptures is significantly less likely to cross the tibial and femoral physes compared with that in skeletally mature patients.[28] However, although the physis has a shock-absorbing function, the bone bruise still extends to the metaphysis of the tibia and femur in 25% and 4%, respectively, of skeletally immature patients.[28] We speculate that this occurs because the energy exceeds the shock-absorbing function of the physis. Therefore, we classified bone bruises into 3 grades according to their depth on MRI. Grade I bone bruising reflects a situation in which the energy is completely absorbed in the physis, grade II occurs when the energy reaches the limit of the shock-absorbing ability of the physis, and grade III occurs when the energy exceeds the limit of the shock-absorbing ability of the physis.

Previous studies have established that a bone bruise is an indicator of associated lesions in the injured knee of pediatric patients with ACL tears.[1] Bone bruises affecting both the lateral and medial compartments are significantly associated with MCL and LCL injuries.[1,17] The prevalence of collateral ligament injuries in patients with ACL tears and bone bruises ranges from 19% to 26%.[3,23] One study of patients with ACL injuries and bone bruises reported MCL lesions in 9 of 54 (17%) patients and LCL lesions in 1 (2%) patient.[3] The prevalence of collateral ligament injuries (20.9%) in our study population was similar to that reported in previous studies; however, the real prevalence of collateral ligament injuries may have been greater because the collateral ligament injuries in our study were identified and graded using both MRI and physical examination findings rather than only MRI, as utilized in previous studies. Moreover, our study documented grade 2 and 3 collateral ligament tears that resulted in mild or gross instability requiring surgical management. In addition, these previous studies did not provide an exact description of the severity of a collateral ligament injury. The prevalence of collateral ligament injuries in our study increased in tandem with the bone bruise depth; the prevalence was only 1.9% in patients with grade I bone bruises compared with 45.5% in patients with grade III bone bruises. This may be because of increased anterior translation of the tibia relative to the femur, the degree of knee valgus, and hyperextension under the increased energy from grade I to III. Also, given our large female population, this could be related to

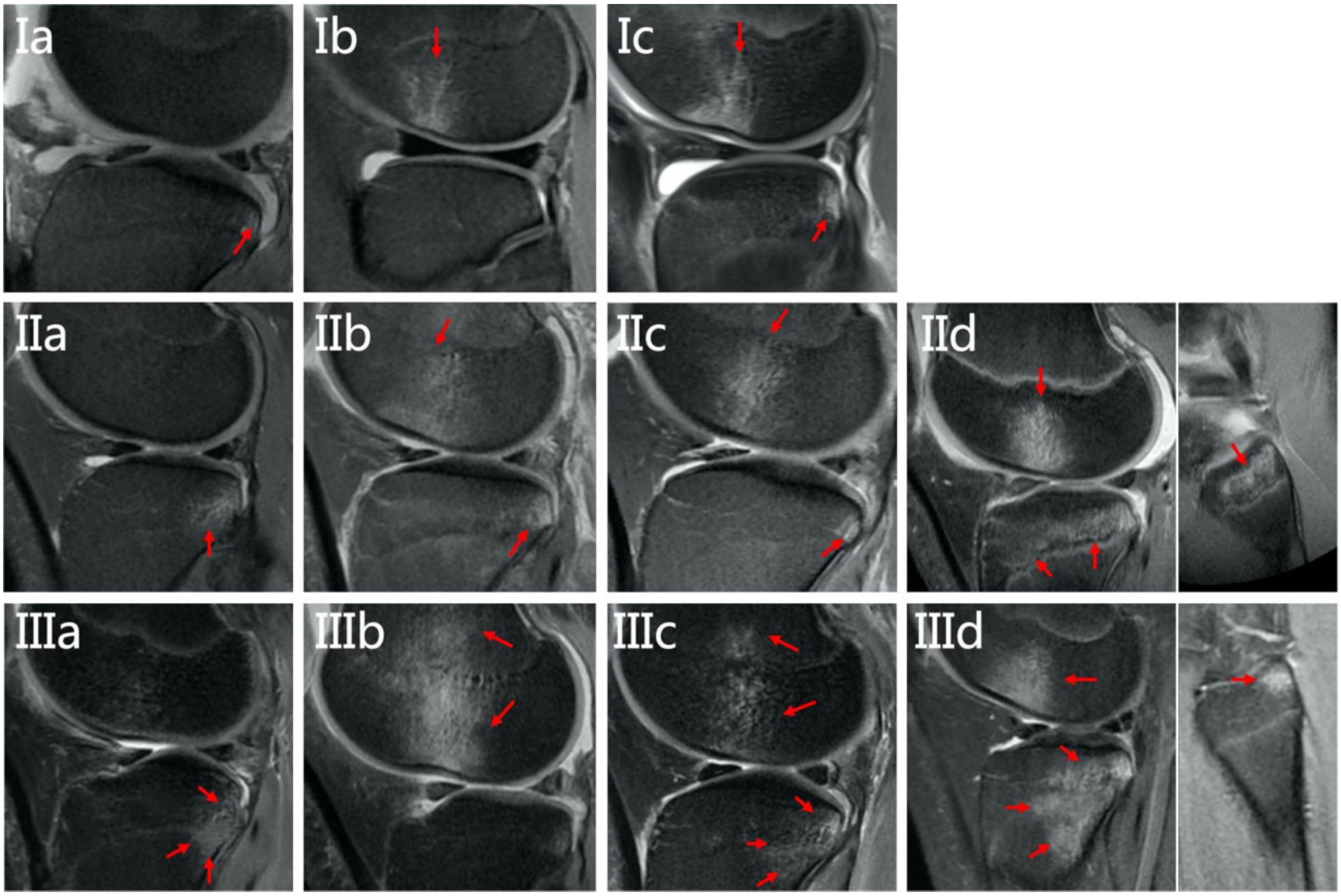

Figure 2. Sagittal-plane magnetic resonance imaging illustrating the classification of bone bruises in pediatric patients with anterior cruciate ligament injuries. The red arrow indicates the bone bruise area. Ia: Bone bruise located on the posterior lateral tibial plateau and within the epiphysis. Ib: Bone bruise located on the lateral femoral condyle and within the epiphysis. Ic: Bone bruise located on the posterior lateral tibial plateau and lateral femoral condyle; the bone bruise of both the lateral tibial plateau and lateral femoral condyle was within the epiphysis. IIa: Bone bruise located on the posterior lateral tibial plateau and reaching the epiphyseal plate. IIb: Bone bruise located on the posterior lateral tibial plateau and lateral femoral condyle; the bone bruise of the lateral femoral condyle reached the epiphyseal plate. IIc: Bone bruise located on the posterior lateral tibial plateau and lateral femoral condyle; the bone bruise of both the lateral tibial plateau and lateral femoral condyle reached the epiphyseal plate. IId: Bone bruise located on the posterior lateral tibial plateau, lateral femoral condyle, and fibular head; the bone bruise of the lateral tibial plateau reached the epiphyseal plate. IIIa: Bone bruise located on the posterior lateral tibial plateau and lateral femoral condyle; the bone bruise of the lateral tibial plateau extended to the metaphysis. IIIb: Bone bruise located on the posterior lateral tibial plateau and lateral femoral condyle; the bone bruise of the lateral femoral condyle extended to the metaphysis. IIIc: Bone bruise located on the posterior lateral tibial plateau and lateral femoral condyle; the bone bruise on both the lateral tibial plateau and lateral femoral condyle extended to the metaphysis. IIId: Bone bruise located on the posterior lateral tibial plateau, lateral femoral condyle, and fibular head; the bone bruise of the lateral tibial plateau extended to the metaphysis. Sometimes, the deepest bone bruise area can be of a different grade in 2 locations; for example, for IIId, the bone bruise crosses the physis on the tibia, but it does not cross the physis on the femur.

generalized ligamentous laxity, which is seen more commonly in female patients.

To date, only Bordoni et al[3] have investigated cartilage lesions in pediatric patients with a torn ACL, reporting that 3.7% of pediatric patients with ACL tears and bone bruises displayed cartilage lesions. In the current study, 14.4% of patients had cartilage lesions. Although the prevalence of cartilage lesions in our study is higher than that reported by Bordoni et al,[3] it is still much lower than that reported in adults (59%-80%). The lower prevalence of cartilage lesions in pediatric patients may be because pediatric patients typically incur less trauma-sustained energy due to the greater elasticity of and reduced tendency for traumatic ruptures of joint tissue in pediatric patients than adults.[3] Although the prevalence of cartilage lesions did not significantly differ among the 3 bone bruise grades, there was a tendency for the number of cartilage lesions to increase from grade I to grade III.

Previous studies have reported that 43% to 47.2% of pediatric patients have meniscal tears.[3,28] In the present study,

TABLE 3
Classification of Bone Bruises[a]

Type	Grade I	Grade II	Grade III	Total
a	12 (7.8)	30 (19.6)	24 (15.7)	66 (43.1)
b	12 (7.8)	4 (2.6)	6 (3.9)	22 (14.4)
c	30 (19.6)	15 (9.8)	9 (5.9)	54 (35.3)
d	0 (0.0)	6 (3.9)	5 (3.3)	11 (7.2)
Total	54 (35.3)	55 (35.9)	44 (28.8)	153 (100.0)

[a]Data are reported as n (%).

TABLE 4
Associated Lesions by Classification of Bone Bruise[a]

Lesion/Type	Grade I	Grade II	Grade III	*P* Value
Cartilage				
a	1 (8.3)	5 (16.7)	6 (25.0)	.460
b	1 (8.3)	1 (25.0)	0 (0.0)	.417
c	2 (6.7)	2 (13.3)	2 (22.2)	.413
d	0 (0.0)	1 (16.7)	1 (20.0)	.892
Total	4 (7.4)	9 (16.4)	9 (20.5)	.172
Collateral ligament				
a	0 (0.0)	4 (13.3)	8 (33.3)	**.034**
b	0 (0.0)	1 (25.0)	3 (50.0)	**.038**
c	1 (3.3)	5 (33.3)	5 (55.6)	**.001**
d	0 (0.0)	1 (16.7)	4 (80.0)	**.045**
Total	1 (1.9)	11 (20.0)	20 (45.5)	**<.001**
Meniscus				
a	4 (33.3)	18 (60.0)	14 (58.3)	.268
b	8 (66.7)	2 (50.0)	3 (50.0)	.741
c	16 (53.3)	12 (80.0)	9 (100.0)	**.017**
d	0 (0.0)	4 (66.7)	3 (60.0)	.827
Total	28 (51.9)	36 (65.5)	29 (65.9)	.249

[a]Data are reported as n (%). Boldface *P* values indicate a statistically significant difference between grades ($P < .05$).

60.8% of the pediatric patients had a meniscal tear. The higher prevalence of meniscal tears in our cohort may be attributed to the fact that we evaluated meniscal tears mainly based on intraoperative findings, while previous studies used MRI, which may decrease the detection of meniscal tears. Additionally, one study reported an equal distribution between medial and lateral meniscal injuries,[31] and another reported rates of 39.7% for lateral meniscal tears and 46.6% for medial meniscal tears.[38] The prevalence of medial and lateral meniscal lesions in the present study was 37.6% (35/93) and 36.6% (34/93), respectively. These findings are similar to those of previous studies. Interestingly, the prevalence of meniscal tears significantly differed among grades in patients with type c bone bruises. We speculate that this may be associated with the different patterns of energy release during an ACL injury in type c bone bruises.

There is a lack of literature that clearly summarizes and classifies the anatomic distribution pattern of bone bruises in pediatric patients with ACL tears. Only Novaretti et al[28] reported a classification system of the bone bruise distribution pattern, with 3 parts on the tibial side and 2 parts on the femoral side. However, this classification system categorized the tibial and femoral sides separately.[28] To standardize the bone bruise location by grade, we classified the anatomic distribution pattern of bone bruises into 4 types according to their characteristics. There were 3 characteristics of bone bruises in pediatric patients with ACL injuries. First, all bone bruises were located on the lateral side of injured knees, with or without accompanying bone bruises on the medial side. Bordoni et al[3] reported that a bone bruise was on the lateral femoral condyle in 80% of pediatric patients, the lateral tibial plateau in 83%, the medial femoral condyle in 37%, and the medial tibial plateau in 20%. Novaretti et al reported that a bone bruise was on the lateral femoral condyle in 96% of patients, the lateral tibial plateau in 28%, and the medial femoral condyle in 38%. Although neither of these 2 studies distinguished between the presence of bone bruises on the lateral femoral condyle versus lateral tibial plateau, nearly all patients had bone bruises on the lateral side. In the current study, the bone bruise was on the lateral femoral condyle in 88.9% of patients, the lateral tibial plateau in 90.8%, and both the lateral femoral condyle and lateral tibial plateau in 79.7% . All 153 patients had bone bruises on the lateral side, while 51.0% of patients had bone bruises on both the lateral and the medial sides. These results are consistent with previous studies.[33,34] Second, the bone bruise depth on the lateral side could be divided into 3 conditions: deeper bone bruise on the lateral tibial plateau, deeper bone bruise on the lateral femoral condyle, and equal bone bruise depth on the lateral tibial plateau and lateral femoral condyle. The bone bruise was deeper on the lateral side than the medial side in the present study. The difference in bone bruise depth between the lateral and medial sides may be attributed to the mechanism of injury, such as valgus rotation, internal rotation, or both.[2,30] Third, 11 of 153 (7.2%) patients with bone bruises on the lateral femoral condyle and lateral tibial plateau also had a bone bruise on the fibular head. The tibiofibular arch plays an important role in bearing downward forces of the lateral compartment of the knee joint.[5,16] Therefore, we speculate that bone bruises of the fibular head occurred because of a large degree of traumatic energy that could not be limited to the lateral tibial plateau. Our hypothesis was supported by our finding that no patient had a grade I bone bruise classified as type d, which shows that the energy was too small to reach the fibular head in patients with grade I bone bruises.

The timing of MRI has a major effect on the reliability of bone bruise patterns. Although a 6-week threshold has commonly been used in previous studies, a 4-week threshold was selected in the present study to further minimize timing errors and preserve the signal characteristics of bone bruises.[13] A longitudinal study showed that the bone bruise volume begins decreasing at 4 weeks after an ACL injury.[35] Bone bruises are reportedly observed in 68.0% to 71.0% of adult patients with ACL injuries who undergo

MRI within 6 weeks after the injury.[8,36] This prevalence rises to 81.6% to 86.0% when MRI is performed within 4 weeks after an injury.[15,32] Bone bruises are reportedly observed in 69.2% of pediatric patients with ACL injuries who undergo MRI within 6 weeks after the injury,[3] which is lower than our prevalence of 81.4% (n = 153) in pediatric patients who underwent MRI within 4 weeks after the injury. Therefore, changes in the bone bruise volume may still have resulted in errors in the determination of grades and types using this new classification system.

Limitations

There are some limitations to the current study. First, the bone bruise depth was associated with the energy of the injury, but it remains unclear how much energy can be absorbed in the physis before the bone bruise extends to the metaphysis. However, it is difficult to obtain these data from patients. Second, a bone bruise of the fibular head has not been previously reported in pediatric patients with ACL injuries; biomechanical testing is needed to confirm whether the injury mechanism is different from that of bone bruises with other distribution patterns. Third, although the current study cohort comprised 153 of 188 patients, there were too few male patients to evaluate sex-specific differences in bone bruise severity. Finally, we excluded those who were skeletally mature, while the age range of the included patients was close to the end stage. There is likely a difference in the physis structure based on overall maturity. This fact resulted from the rare occurrence rate of ACL injuries in young children. Further studies are needed to quantify shock-absorbing limitations of the physis for each of the bone bruise grades using biomechanical testing. In addition, more male patients are required to investigate sex-associated differences in the bone bruise distribution, associated lesions, and long-term outcomes of pediatric patients with ACL injuries.

CONCLUSION

In this study, we presented a new classification system for the depth and location of bone bruises in pediatric patients with complete primary ACL tears. This new system provides a basis for estimating associated lesions of the knee before surgery. The prevalence of collateral ligament injuries increased in accordance with the bone bruise grade (from grade I to III). All patients with grade III type c bone bruises had meniscal lesions.

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