

# A Case-Control Study Comparing Bone Bruising and Intra-articular Injuries in Patients Undergoing Anterior Cruciate Ligament Reconstruction With and Without Medial Collateral Ligament Tears

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**Background:** Concomitant injuries can occur in patients with combined anterior cruciate ligament (ACL) and medial collateral ligament (MCL) tears; however, no studies have compared these injuries in patients undergoing ACL reconstruction with an MCL tear to those with an intact MCL.

**Purpose:** To compare bone bruising, meniscus tears, and chondral lesions in patients undergoing ACL reconstruction with an MCL tear (cases) to those with an intact MCL (controls).

**Study Design:** Case-control study; Level of evidence, 3.

**Methods:** Thirty-two cases and 352 controls were identified from a prospective registry. Bone bruising was confirmed on magnetic resonance imaging, and meniscus tears and chondral lesions were confirmed arthroscopically. Demographics and concomitant injuries were compared between cases and controls using exact chi-square tests. Multivariate logistic regression was used to calculate odds ratios (ORs) and 95% CIs adjusted for age, sex, body mass index, and mechanism and type of injury.

**Results:** Cases had significantly more contact injuries than controls (58.1% vs 21.3%,  $P < .0001$ ). The prevalence and odds of bone bruising of the lateral tibial plateau (89.7% vs 84.6%;  $P = .59$ ; OR, 3.53; 95% CI, 0.45-27.71), lateral femoral condyle (82.8% vs 72.8%;  $P = .28$ ; OR, 1.94; 95% CI, 0.64-5.88), medial tibial plateau (20.7% vs 31.7%;  $P = 0.29$ ; OR, 0.53; 95% CI, 0.19-1.53), and medial femoral condyle (6.9% vs 8.3%;  $P \geq .999$ ; OR, 1.07; 95% CI, 0.21-5.40) did not differ significantly between cases and controls. The prevalence and odds of lateral meniscus tears (53.3% vs 43%;  $P = .34$ ; OR, 1.85; 95% CI, 0.76-4.52), medial meniscus tears (31.3% vs 33.5%;  $P = .85$ ; OR, 0.90; 95% CI, 0.37-2.21), and chondral lesions (16% vs 10.8%;  $P = .50$ ; OR, 0.70; 95% CI, 0.15-3.21) also did not significantly differ between cases and controls.

**Conclusion:** ACL-MCL injuries were most often due to a contact mechanism, whereas ACL tears without associated MCL injury were more frequently due to a noncontact mechanism. However, there were no significant differences in concomitant injuries in ACL-MCL knees versus ACL knees.

**Keywords:** anterior cruciate ligament; medial collateral ligament; bone bruising; meniscus tear; chondral lesion

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The 2 most commonly injured ligaments of the knee are the anterior cruciate ligament (ACL) and the medial collateral ligament (MCL).<sup>5</sup> The prevalence of combined ACL-MCL injuries ranges from 19% to 38% and has been increasing in recent years.<sup>4,8,21</sup> Potential mechanisms of ACL-MCL injuries include a blow to the lateral side of the thigh or a valgus force to the knee when the tibia is externally rotated and the femur is stable.<sup>1</sup> Treatment of combined ACL-MCL injuries is controversial; however, the ACL is typically reconstructed, and grades I and II MCL tears are managed nonoperatively while grade III MCL tears may require surgery.<sup>1,5</sup>

Concomitant injuries in patients with combined ACL-MCL tears have been reported in the literature and might be the result of a different mechanism of injury or higher energy injuries.<sup>2,3,8,14,15,20,21</sup> Several studies have found that lateral meniscus tears (18%-80%) are more prevalent than medial meniscus tears (0%-28%) in the presence of ACL-MCL tears.<sup>2,3,8,14,15,20</sup> Bone bruising seen on magnetic resonance imaging (MRI) has also been observed in patients with ACL-MCL injuries.<sup>15,21</sup> Yoon et al<sup>21</sup> found ACL-MCL tears in 19% of patients with lateral bone bruising and in 31% with medial and lateral bone bruising. Nakamura et al<sup>15</sup> found that 10 of 17 patients with ACL-MCL tears had bone bruising on the lateral femoral condyle (LFC) or lateral tibial plateau (LTP), and 5 of these patients had chondral lesions at the site of bone bruising. The prevalence of chondral injuries in patients with ACL-MCL injuries is generally low, ranging from 6% to 22%.<sup>2,3,14</sup>

No studies have directly compared concomitant injuries (bone bruising, meniscus tears, and chondral lesions) in patients undergoing ACL reconstruction with an MCL tear (ie, ACL-MCL) to those with an intact MCL (ie, ACL-no MCL), which is the aim of this case-control study. It was hypothesized that cases with combined ACL-MCL tears would have fewer medial meniscus tears and medial tibial plateau (MTP) bruising and more lateral meniscus tears and LTP bruising than controls with ACL-no MCL injuries.

## METHODS

### Sample Selection

Patients were selected from a prospective registry of 937 ACL reconstructions performed between January 2005 and June 2015 at a single institution. This study was approved by an institutional review board. Inclusion criteria were no previous surgery on the injured knee, MRI within 6 weeks of injury, and surgery within 3 months of injury. Patients not meeting this criteria were excluded, as well as patients with grade I MCL tears. After applying the exclusion criteria, we had 32 cases with ACL tears and grade II or III MCL tears and 352 controls (ACL tear with no MCL injury).

### Data Collection

Demographics, injury characteristics, and MRI findings were documented preoperatively on standard data collection forms by 4 study surgeons, and arthroscopic findings were also documented immediately after surgery. Preoperative data were sex (male/female), date of injury, age at injury, body mass index (BMI), injured side (right/left), history of knee surgery (yes/no), mechanism of injury (contact/noncontact), and type of injury (high-impact sports-related/other sports-related/not sports-related or unknown type). High-impact sports included basketball, football, soccer, and skiing. In accordance with the World Health Organization standards, BMI was categorized as normal ( $\leq 24.99$  kg/m<sup>2</sup>), overweight (25-29.99 kg/m<sup>2</sup>), and obese ( $\geq 30$  kg/m<sup>2</sup>). The study surgeons read the MRIs, which were performed within

6 weeks of injury at various facilities. MCL injuries and bone bruising were evaluated by MRI. The grade of MCL injury for the purposes of the study was taken from the grade on clinical examination, with grade II and greater injuries being characterized as those with detectable valgus opening at 30° of flexion when compared with the opposite side. Injuries without detectable valgus opening at 30° of flexion were excluded to avoid inadvertently confusing other sources of medial joint line pain (ie, bone bruising, meniscal tears, local contusions, etc) with injury to the MCL. Bone bruising on sagittal and coronal MRI images was documented for each of the following anatomic sites: LTP, MTP, LFC, and medial femoral condyle (MFC). Meniscus tears and chondral injuries were confirmed arthroscopically.

### Statistical Analysis

Descriptive statistics were calculated for demographics, MRI findings, and arthroscopic findings in cases and controls. Data for cases and controls were compared with exact chi-square tests. Unadjusted and adjusted logistic regression was used to examine the odds of bone bruising and intra-articular injuries in cases versus controls. Regression models were minimally adjusted for age and sex and further adjusted for potential confounders, including BMI, mechanism, and type of injury. Unadjusted and adjusted odds ratios (ORs) and 95% CIs are reported. Statistical significance was considered when  $P < .05$  or when the null value (1.00) was absent from the CI. Statistical analyses were performed using SAS 9.4 (SAS Institute Inc).

## RESULTS

Mechanism of injury differed significantly between cases and controls (Table 1) such that the majority of cases had contact injuries (58.1%) and the majority of controls had noncontact injuries (78.7%,  $P < .0001$ ). There were no other statistically significant differences in age, sex, BMI, injured side, type of injury, bone bruising, and intra-articular injuries for cases versus controls (Tables 1 and 2). Results of the unadjusted and adjusted logistic regression models are presented in Table 3. The odds of lateral and medial bone bruising, lateral and medial meniscus tears, and chondral lesions were not statistically significantly different for cases versus controls.

## DISCUSSION

Previous studies have shown that combined ACL-MCL tears are more frequently associated with concomitant injuries, which may be due to higher energy injuries.<sup>2,3,8,14,15,20,21</sup> However, no studies have directly compared the prevalence of concomitant injuries, including bone bruising, meniscus tears, and chondral lesions, in patients with ACL-MCL tears versus ACL-no MCL tears. In the current study, we found that the majority of cases with ACL-MCL injuries had contact injuries while the majority of controls with ACL-no

TABLE 1  
Demographics Stratified by Case-Control Status<sup>a</sup>

Characteristic	Cases, n (%)	Controls, n (%)	P
Age, y <sup>b</sup>			.14
<17	8 (25.8)	126 (36.2)	
18-28	9 (29)	124 (35.6)	
>28	14 (45.2)	98 (28.2)	
Sex			.10
Males	22 (68.8)	187 (53.1)	
Females	10 (31.3)	165 (46.9)	
Body mass index, kg/m <sup>2b</sup>			.74
<24.99	16 (51.6)	190 (55.9)	
25-29.99	10 (32.3)	113 (33.2)	
≥30	5 (16.1)	37 (10.9)	
Injured side <sup>b</sup>			≥ .999
Right	16 (53.3)	183 (52.6)	
Left	14 (46.7)	165 (47.4)	
Mechanism of injury <sup>b</sup>			<.0001
Contact	18 (58.1)	70 (21.3)	
Noncontact	13 (41.9)	258 (78.7)	
Type of injury <sup>b</sup>			.19
High-impact sports-related <sup>c</sup>	11 (34.4)	177 (51.2)	
Other sports-related	16 (50)	135 (39)	
Not sports-related or unknown	5 (15.6)	34 (9.8)	

<sup>a</sup>Cases had an anterior cruciate ligament (ACL) tear plus grade II or III medial collateral ligament (MCL) tear (n = 32) and controls had an ACL tear with an intact MCL (n = 352).

<sup>b</sup>Less than 10% of data were missing for this variable.

<sup>c</sup>High-impact sports include basketball, football, soccer, and skiing.

MCL injuries had noncontact injuries. Contrary to our hypotheses, we found no statistically significant differences in the prevalence and odds of bone bruising, meniscus tears, and chondral lesions in cases versus controls.

We found that combined ACL-MCL injuries primarily resulted from contact injuries, which is consistent with previous literature.<sup>13</sup> ACL-MCL injuries are often caused by contact or collision during sports such as football, rugby, and soccer and result in valgus stress and combined tibial external rotation.<sup>5,13</sup> Paul et al<sup>18</sup> compared comorbid knee pathology in 263 patients undergoing ACL reconstruction for jumping versus nonjumping injuries. The prevalence of MCL injuries was greater for nonjumping injuries (12%) versus jumping injuries (4.3%), and most of the nonjumping injuries involved a contact mechanism.

Two studies have examined bone bruising on MRI in patients with ACL-MCL injuries. Yoon et al<sup>21</sup> examined patients undergoing ACL reconstruction and found that MCL injuries were present in 6 of 32 (19%) patients with lateral bone bruising and 11 of 35 (31%) patients with lateral and medial bone bruising. This study demonstrated that MCL injuries were more prevalent when bone bruising was more extensive; however, the authors did not distinguish between tibial and femoral bone bruising. Nakamura et al<sup>15</sup> found that 10 of 17 (58.8%) patients with ACL-MCL tears had bone bruising on the LTP and/or LFC; however, the authors do not mention whether medial bone bruising

TABLE 2  
Bone Bruising and Intra-articular Injuries Stratified by Case-Control Status<sup>a</sup>

	Cases, n (%)	Controls, n (%)	P
MRI findings			
Lateral tibial plateau bone bruising <sup>b</sup>			.59
Present	26 (89.7)	264 (84.6)	
Absent	3 (10.3)	48 (15.4)	
Medial tibial plateau bone bruising <sup>b</sup>			.29
Present	6 (20.7)	99 (31.7)	
Absent	23 (79.3)	213 (68.3)	
Lateral femoral condyle bone bruising <sup>b</sup>			.28
Present	24 (82.8)	227 (72.8)	
Absent	5 (17.2)	85 (27.2)	
Medial femoral condyle bone bruising <sup>b</sup>			≥ .999
Present	2 (6.9)	26 (8.3)	
Absent	27 (93.1)	286 (91.7)	
Arthroscopic findings			
Medial meniscus tear			.85
Present	10 (31.3)	118 (33.5)	
Absent	22 (68.8)	234 (66.5)	
Lateral meniscus tear <sup>b</sup>			.34
Present	16 (53.3)	145 (43)	
Absent	14 (46.7)	192 (57)	
Chondral lesions <sup>b</sup>			.50
Present	4 (16)	27 (10.8)	
Absent	21 (84)	223 (89.2)	

<sup>a</sup>Cases had an anterior cruciate ligament (ACL) tear plus a grade II or III medial collateral ligament (MCL) tear (n = 32), and controls had an ACL tear with an intact MCL (n = 352). MRI, magnetic resonance imaging.

<sup>b</sup>Less than 10% of data were missing for this variable.

was observed. Compared with these studies,<sup>15,21</sup> we found a much greater prevalence of lateral bone bruising (>80%). Although not statistically significant, the odds of LTP bruising were increased in our study and the odds of MTP bruising were decreased for ACL-MCL injuries versus ACL-no MCL injury, which was consistent with our hypotheses.

In 1950, O'Donoghue<sup>17</sup> defined the "unhappy triad" as a combination of injuries to the ACL, MCL, and medial meniscus. However, recent research has found that lateral meniscus tears (18%-80%) are more prevalent than medial meniscus tears (0%-28%) in patients with combined ACL-MCL injuries, which is consistent with our findings.<sup>2,3,8,14,15,20</sup> In patients with ACL-MCL tears, we found that 53% had lateral meniscus tears and 31% had medial meniscus tears. Although not statistically significant, the odds of lateral meniscus tears were increased and the odds of medial meniscus tears were decreased for ACL-MCL injuries versus ACL-no MCL injury, which is consistent with our hypotheses. The shift toward more lateral than medial meniscus tears with ACL-MCL injuries over time may be explained by the inception of arthroscopy, since the diagnoses in earlier studies were confirmed instead by arthrotomy, which could have limited the assessment of the posterior lateral compartment of the knee.<sup>3,17,20</sup> Meniscal tears likely result from the same forces that injure the ACL and MCL, which also disturb the medial compartment and

TABLE 3

Unadjusted and Adjusted Associations Between Bone Bruising and Intra-articular Injuries for Cases Versus Controls<sup>a</sup>

	No. With Pathology (Cases:Controls)	Unadjusted Model, OR (95% CI)	Age- and Sex-Adjusted Model, OR (95% CI)	Fully Adjusted Model, <sup>b</sup> OR (95% CI)
Bone bruising site				
Lateral tibial plateau	25:234	4.59 (0.61, 34.81)	4.07 (0.53, 31.23)	3.53 (0.45, 27.71)
Lateral femoral condyle	21:198	1.68 (0.61, 4.60)	1.83 (0.63, 5.34)	1.94 (0.64, 5.88)
Medial tibial plateau	5:87	0.52 (0.19, 1.42)	0.47 (0.17, 1.32)	0.53 (0.19, 1.53)
Medial femoral condyle	2:22	0.97 (0.21, 4.36)	0.98 (0.21, 4.54)	1.07 (0.21, 5.40)
Lateral meniscus tears	15:126	1.71 (0.77, 3.77)	1.72 (0.75, 3.95)	1.85 (0.76, 4.52)
Medial meniscus tears	9:101	0.94 (0.41, 2.13)	0.77 (0.33, 1.78)	0.90 (0.37, 2.21)
Chondral lesions	4:24	1.70 (0.53, 5.42)	1.18 (0.33, 4.25)	0.70 (0.15, 3.21)

<sup>a</sup>Cases had an anterior cruciate ligament (ACL) tear plus a grade II or III medial collateral ligament (MCL) tear (n = 32), and controls had an ACL tear with an intact MCL (n = 352). Missing covariate data were excluded from the analyses. OR, odds ratio.

<sup>b</sup>Adjusted for age, sex, body mass index, mechanism of injury, and type of injury.

compress the lateral compartment in combination with rotational stress to the knee.<sup>3</sup>

Similar to previous studies, we found a low prevalence of chondral lesions (16%) in patients with ACL-MCL injuries.<sup>2,3,14,15</sup> We also found no significant difference in the odds of chondral lesions for patients with ACL-MCL injuries versus ACL-no MCL injuries. Nakamura et al<sup>15</sup> found that 29.4% of patients with ACL-MCL injuries had chondral lesions on the LFC or LTP at the site of bone bruising. At the site of LFC bruising, 3 grade I and 2 grade II chondral lesions were found. At the site of LTP bruising, 2 grade I, 2 grade II, and 1 grade III chondral lesions were found. Barber<sup>2</sup> compared concomitant knee injuries in 23 skiers versus 41 nonskiers with ACL-MCL injuries. Five skiers had chondral injuries, of which the MFC was involved in 3 and patellar articular cartilage in 2. Five nonskiers also had chondral injuries, of which the MFC was involved in 1, the patella in 2, and the LTP in 2. Also, 14% of 50 patients with ACL-MCL tears in another study by Barber<sup>3</sup> had chondral lesions, of which the MFC was involved in 3, the LTP in 2, and the patella in 2. Cartilage degradation usually occurs gradually over many years, and the prevalence of chondral lesions has been shown to increase with increasing age in patients undergoing ACL reconstruction.<sup>6,10-12</sup> Perhaps the prevalence of chondral lesions in patients with ACL-MCL injuries is generally low because the majority of patients in the current and previous studies were 30 years old or younger. Alternatively, energy from the injury may have been dissipated through the MCL tear, relieving stress on the cartilage.

Concomitant knee pathology should be considered during treatment planning, since clinical outcomes can vary with different patterns of injury. In patients undergoing ACL reconstruction, meniscus tears and chondral lesions may be associated with diminished long-term clinical outcomes and degenerative changes.<sup>7,16</sup> Bone bruising may lead to increased pain as well as longer recovery of range of motion and time to unaided ambulation after ACL reconstruction.<sup>9,19</sup> Zaffagnini et al<sup>22</sup> compared outcomes for patients with combined ACL-MCL tears versus ACL-no MCL tear; however, they excluded patients with concomitant meniscus injuries. Increased valgus laxity was

found in the ACL-MCL group; however, there were no statistically significant group differences in clinical outcome scores.

One strength of this study includes making a direct comparison between concomitant injuries in patients with combined ACL-MCL tears versus ACL-no MCL, which has not been examined in previous studies to our knowledge. Also, in comparison with previous studies, we had a fairly large sample size with 32 ACL-MCL cases and 352 ACL-no MCL controls.<sup>14,15,21</sup> There are also several limitations of this study. MRIs were performed at various facilities and thus random error may have occurred as a result of differences in equipment and radiology technician skill across sites. The results of this study may not be generalizable to patients undergoing nonoperative management. The temporality of injuries is unknown; intra-articular injuries may have occurred before ACL and MCL injuries. Although MRIs were performed within 6 weeks and surgery was performed within 3 months of injury, bone bruising may have diminished and secondary injuries may have occurred during this period.

## CONCLUSION

Contact injuries occurred most frequently in patients with combined ACL-MCL injuries and noncontact injuries occurred most frequently in patients with ACL-no MCL injuries. However, there were no statistically significant differences in concomitant injuries for patients with ACL-MCL injuries versus ACL-no MCL injuries.

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