

# Bone Marrow Contusion Pattern of Recent Knee Injury on MRI and its Correlation with the Type of Knee Injury

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## ABSTRACT

**Introduction:** High grade exposure of force beyond knee-joint physiologic range will lead to occult edematous and haemorrhagic bone change due to trabecular micro fractures and soft-tissue structure damage. Primary aim of study was to identify imaging pattern of bone marrow edema resulting from five different mechanisms and to correlate this patterns of bone marrow edema retrospectively with type of knee injury by clinical history and secondary aim was to determine the most common associated ligamentous injury.

**Material and methods:** Cross-sectional study was conducted on 100 patients of age more than 18 years. On the basis of bone marrow contusion pattern on MRI images, suspected mode of injury was predicted and was correlated with the history which was obtained from the patient or attendant. Associated ligament injuries were also evaluated.

**Results:** Most common bone marrow contusion pattern was pivot shift injury with 54 % cases followed by clip injury 25% cases and 7% cases each of dashboard injury, hyperextension injury and lateral patellar shift injuries. Most common location of marrow edema in pivot shift pattern were found to be Posterolateral tibial plateau (98.1%), mid portion of lateral femoral condyle (87.0%) and postero- medial tibial plateau ( 46.2 %). Most common mode of injury was road traffic accident.

**Conclusion:** Pivot shift pattern was the most common contusion pattern and the most common mode of injury was road traffic accident followed by sports related injury. By applying a biomechanical approach in MR interpretation, it is possible to predict associated injuries like meniscus and ligament tear etc. Prediction of this associated injuries may lead to better evaluation of knee joint.

**Keywords :** MRI; Knee Injury; Contusion; Bone marrow

## INTRODUCTION

Knee joint is major weight bearing joint which allows stability & mobility while balancing and doing routine daily activity.<sup>1</sup> Multiple structures are fulfilling this range of movement and function.<sup>2</sup> If high grade exposure of force beyond knee joints physiologic range is applied, it will lead to injuries to bone or soft tissue structures. The contusions of bone marrow are commonly used to define as occult edematous and hemorrhagic bone changes due to trabecular micro fractures. Hyper perfusion and increased interstitial water content contributes to edema.<sup>2</sup> Cortex and articular cartilage of bone should be intact if we are suspecting bone marrow contusion. Depending upon the applied force of magnitude and position of knee during injury, the location and severity of structural

damage is suspected Injuries associated with single force are considered simple mechanisms, whereas combinations of multiple forces are associated with complex mechanisms.<sup>3</sup> Bone marrow contusions may result from direct impact, compressive forces or tractional forces. Traumatic forces can result from noncontact or contact injuries.<sup>4</sup> MRI is the modality of choice for evaluation of bone marrow pathology.<sup>2</sup> Mild bone marrow contusion is seen as high signal intensity in STIR sequences and hypointense on T1w images. Sanders et al has described five patterns of contusion with associated soft tissue injuries: 1) Pivot shift injury, 2) Dashboard injury, 3) Clip injury, 4) Hyperextension injury and 5) Lateral patellar dislocation.<sup>5</sup>

## MATERIAL AND METHODS

Following institutional ethical committee approval, 100 patients of age more than 18 years fulfilling the inclusion criteria were enrolled in this study. Detailed history and clinical examination of all patients was taken and records were kept by the orthopedic department. Convenient sampling technique was used and the study was cross sectional study. The study period was January 2019 to March 2020. Inclusion criteria was patients more than 18 years with recent knee injuries less than 6 weeks referred for MRI examination and exclusion criteria were mimics of bone marrow contusion like infectious etiology, neoplasm or postoperative knee joint, patients where MRI is contraindicated. Written informed consent was obtained from all the patients prior to the study procedure. The study was done using 1.5 Tesla Siemens ESSENZA MRI machine. The sample size included was 100.

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### Assessment

PDFS axial, PDFS sagittal, PDFS coronal, T2 TSE sagittal, T2 TIRM coronal and T1 TSE coronal was studied for all patients with recent knee injury. Bone marrow edema analysis was done by a two experienced radiologists with atleast 5 years experience in musculoskeletal imaging. Any discrepancy in interpretation was sorted out by consensus. The interpreting radiologists was blinded to clinical history. The pattern of bone marrow edema was then correlated with patients history. Complete history from patient / attendant was recorded, followed by informed consent. Articular surfaces of tibia and femur were divided in 8 parts. Medial condyles of tibia and femur were divided in three parts – Anterior, Mid and Posterior portion. Lateral condyles of tibia and femur were divided in three parts – Anterior, Mid and Posterior portion. Mid parts of both condyles were divided in two parts – Most anterior portion & Most posterior portion. On the basis of bone marrow contusion pattern on MRI images, suspected mode of injury was predicted and was correlated with the history which was obtained from the patient or attendant. Associated ligament injuries were also evaluated. Meniscal injuries were not assessed. Bone marrow edema was evaluated and classified into five different bone marrow contusions patterns – pivot shift, clip injury, dashboard injury, hyperextension injury and lateral patellar shift injury.

### STATISTICAL ANALYSIS

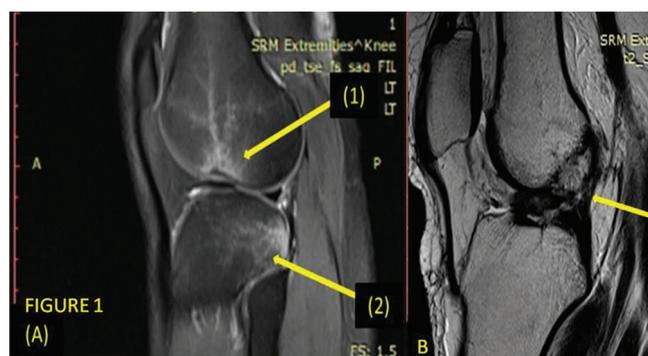
Variables were represented as descriptive statics in frequencies and percentage. Appropriate pie charts and bar chart/ graph were used as. Analysis was done by collecting all the data and entering the same in Microsoft- Word 2010 and Microsoft-Excel 2010 by using Statistical Package for the Social Sciences (SPSS) version 16. P-value less than 0.05 were considered statistically significant.

### RESULTS

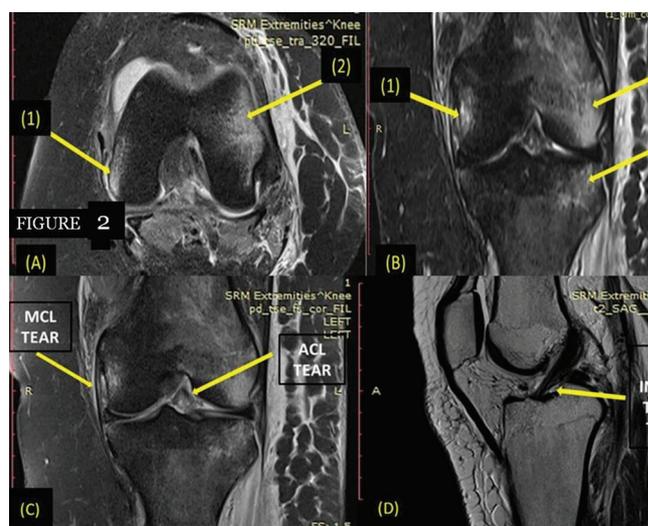
Study was conducted on 100 patients who came to hospital with history of recent (< 6 weeks) of knee injury. Among 100 patients 74 were male and 26 were female. 53 patients were presented with right knee injury and 47 were presented with left knee injury. The age group range was from 18 - 75 years. The maximum patients were from the 18 - 30 year age group, accounting to 61 % cases. In our study, patients with bone marrow contusion and knee injury were examined with MRI and were classified into five different types based on bone marrow contusion patterns involving tibial and femoral condyle. Five different mechanisms of injury were – Pivot shift injury, Clip injury, Dashboard injury, Hyperextension injury and Lateral patellar shift injury in descending order of presentation with 54 cases of pivot shift, 25 cases of clip injury and 7 cases each of dash board, hyperextension and lateral patellar shift injuries.

#### Pivot shift injury

In our study pivot shift injury with twist was most common mechanism of injury while running / walking being a most common mode of injury accounting for 54% cases. Most



**Figure-1:** Showing high signal intensities in postero - lateral tibia (1) and lateral femoral condyle (2) on PDFS – sagittal (Figure – 1a). Discontinuity seen in ACL ligament on T2w images (arrow) (Figure –1b)



**Figure-2:** 2a and B showing high signal intensities in Posterolateral tibia (1), lateral femoral condyle (midportion) (2) and lateral tibial condyle (3) on PDFS – sagittal and coronal images suggesting clip injury. High signal intensity seen in medial collateral ligament and anterior cruciate ligament on Coronal PDFS (yellow arrows in Figure – 2C) suggesting partial medial collateral ligament tear & ACL tear. High signal intensity in ACL on T2 Sagittal (yellow arrow in Figure – 2D) indicating anterior cruciate ligament interstitial tear in case of clip injury.

common location of marrow edema in pivot shift pattern were found to be Posterolateral tibial plateau (98.1%), mid portion of lateral femoral condyle (87.0%) and postero-medial tibial plateau ( 46. 2 %) [Fig.-1] with p-value < 0. 05 which is statistically significant, in our study [Table-1 & 2]. Associated anterior cruciate ligament tear, posterior cruciate ligament tear and medial collateral ligament tear were seen in 53 (94.5%) , 3 (5.5%) and 20 (37 % ) with 0.001, 0.018 and 0.044 p- values respectively which was < 0.05 suggesting significant correlation of these associated injuries with 146 pivot shift injury. Anterior cruciate ligament tear has strong association with compared to posterior cruciate ligament and Medial collateral ligament [Table:3]. Anterior cruciate ligament was most commonly involved ligament (94. 5%) out of other associated ligaments with P-value of 0.001. Least commonly involved ligament was found to be

		Femur							
		Medial condyle			Lateral condyle			Mid portion	
		Ant	Mid	Post	Ant	Mid	Post	Ant	Post
Pivot shift injury	Cases	0	6	2	0	47	7	0	1
	%	0	11.11	4.4	0	87	12.9	0	1.8
	P-Value	0.027	0.001	0.655	0.001	0.001	0.990	0.12	0.354
Clip injury	Cases	0	18	1	2	14	6	0	0
	%	0	72	4	8	56	24	0	0
	P-Value	0.239	0.001	0.735	0.477	0.056	0.051	0.409	0.562
Dashboard Injury	Cases	1	1	0	0	0	0	1	0
	%	14.3	14.3	0	0	0	0	14.3	0
	P-Value	0.150	0.464	0.629	0.311	0.001	0.289	0.016	0.783
Hyperextension Injury	Cases	3	0	0	3	1	0	1	0
	%	42.8	0	0	42.8	14.2	0	14.2	0
	P-Value	0.001	0.104	0.629	0.009	0.001	0.289	0.016	0.783
Lateral patellar shift injury	Cases	0	0	0	6	7	0	0	0
	%	0	0	0	85.7	100	0	0	0
	P-Value	0.575	0.104	0.629	0.001	0.66	0.289	0.695	0.783

**Table-1:** Involvement of femur in different types of injuries

		Tibia								Patella	Fibula
		Medial condyle			Lateral condyle			Mid portion			
		Ant	Mid	Post	Ant	Mid	Post	Ant	Post		
Pivot shift injury	Cases	1	1	25	1	10	53	1	7	2	12
	%	1.8	1.8	46.29	1.8	18.5	98.14	1.857	12.96	3.7	22.2
	P-Value	0.014	0.235	0.005	0.029	0.92	0.001	0.023	0.497	0.001	0.841
Clip injury	Cases	2	2	9	3	8	20	3	1	4	11
	%	8	8	36	12	32	80	12	4	16	44
	P-Value	1.000	0.239	0.807	0.258	0.083	0.044	0.700	0.196	0.337	0.004
Dashboard Injury	Cases	2	1	0	2	1	0	3	2	6	0
	%	28.6	14.3	0	28.6	14.3	0	48.85	28.6	85.7	0
	P-Value	0.037	0.150	0.049	0.020	0.695	0.001	0.003	0.129	0.001	0.134
Hyperextension Injury	Cases	3	0	0	1	0	1	2	1	0	0
	%	42.8	0	0	14.2	0	14.2	28.5	14.2	0	0
	P-Value	0.001	0.575	0.049	0.433	0.170	0.001	0.089	0.773	NA	NA
Lateral patellar shift injury	Cases	0	0	0	0	0	0	0	0	7	0
	%	0	0	0	0	0	0	0	0	100	0
	P-Value	0.419	0.575	0.049	0.452	0.170	0.001	0.360	0.335	0.001	0.134

**Table-2:** Involvement of tibia, fibula and patella in different types of injuries

		ACL	PCL	MCL	LCL
Pivot shift injury	Case	53	3	20	9
	%	94.5	5.5	37	16.66
	P-value	0.001	0.018	0.044	0.295
Clip injury	Case	19	11	20	7
	%	76	44	80	28
	P-value	0.593	0.292	0.001	0.298
Dashboard injury	Case	5	4	3	2
	%	71	58	43	9
	P-value	0.04	0.002	0.229	0.479
Hyperextension injury	Case	6	3	3	2
	%	85.7	43	43	29
	P-value	0.912	0.05	0.246	0.001
Lateral patellar injury	Case	2	0	2	0
	%	29	0	29	0
	P-value	0.004	0.515	0.581	0.758

**Table-3:** Involvement of associated ligaments with different types of injuries

posterior cruciate ligament in our study with 5.6% cases.

### Clip injury

In present study clip injury was second most common mechanism of injury accounting for 25% cases with road traffic accident being the most common mode of injury (68% cases with 0.002 p-Value) followed by sports injury (24%). The rest were domestic accidents and fall. In our study significant correlation was found for postero lateral tibial plateau (80%), midportion of lateral femoral condyle (56%), postero-lateral femoral condyle (24%) and medial femoral condyle (72%) [Fig-2] [Table:1 & 2]. Medial collateral ligament (80% cases) and anterior cruciate ligament (60% cases) [Table:3] involvement was common ligament injuries associated with clip injury. P values for medial collateral ligament tear and anterior cruciate ligament was 0.001 and 0.593 respectively, which suggests significant correlation of clip injury with medial collateral ligament injuries.

### Dash board injury

Dash board injury was third most common contusion pattern accounting with 7% cases. Most common areas of involvement are patella (6 cases-85.7%) and anterior most part of tibia with p-value <0.05 [Table: 1 & 2]. Most common mode of injury was found to be RTA with 100% cases and p value 0.002. In present study ACL was seen more frequently involved (71%) compared to PCL tear (58%) [Table:3].

### Hyperextension injury

Hyperextension injury was seen in 7% cases. Out of 7 cases of hyperextension injury, 5 cases (71.4%) were having kissing contusion due to domestic hyperextension and other 2 cases (28.6%) were hyperextension with valgus component in which medial condylar involvement was seen during sports injury- soccer. Most frequently involved areas were anterior portion of medial condyle of femur and tibia and anterior portion of lateral tibial condyle [Table: 1 & 2] with p-value of 0.001 and most anterior and midpart of tibia with p-value of 0.008. In present study 50% of kissing contusion cases were associated with ACL tears [Table:3].

### Lateral patellar shift

Lateral patellar shift was seen in 7% cases in our study. Most common locations of marrow edema in lateral patellar shift injury were lateral femoral condyle – anterior & mid-part and medial part of patella with statistically significant values [Table: 1 & 2]. Hence significant correlation was found for lateral femoral condyle and medial patellar involvement [Table: 1 & 2]. In associated findings only ACL and medial patellar retinaculum (100%) shows statistically significant correlation with lateral patellar shift injury [Table:3]. Most common mode of lateral patellar shift was found to be RTA in our study.

## DISCUSSION

The knee joint is one of the important weight bearing joint that provides stability, mobility and balance in routine physical activity as well as during standing.<sup>2</sup> When knee is exposed to direct/indirect impact or force beyond physiological range, ligaments/ menisci /soft tissue structures or bones are at risk.<sup>6</sup>

Evaluation of skeleton following trauma by conventional radiograph can reveal presence or absence of fracture while with the help of MRI interpretation, complex injury can be evaluated better.<sup>7,8</sup> In our study, Age group was ranging from 18 to 70 years with majority of patients in 18-30 years age group which was comparable to study done by Majewski et al., 2006 in which majority of the patient were from age group of 20 – 29 years (43.1%).<sup>9</sup>

### Pivot shift injury

In present study pivot shift injury was most common mechanism of injury with twist while running / walking being a most common mode of injury accounting for 54% cases, which was comparable with the study done by Sahoo et al., 2016 and Kaplan et al., 1990, in which most common pattern was pivot shift injury in both studies and 56% cases were accounted in study done by Sahoo et al., 2016.<sup>10,11</sup> In our study most common location of marrow edema in pivot shift pattern were found to be posterolateral tibial plateau (98.1%), mid portion of lateral femoral condyle (midportion) (87.0%) and postero- medial tibial plateau (46.2%) [Fig-1] with < 0.05 p-value which is statistically significant [Table: 1 & 2]. Our study was comparable with article published by Sander's et al., 2000, Sahoo et al., 2016, Kaplan et al., 1999 and Berger et al., 2013 according to which most common location for bone marrow contusion in pivot shift injury was found to be postero-lateral tibial plateau, midportion of the lateral femoral condyle and posterior lip of the medial tibial condyle.<sup>5,10,11,12</sup> In our study associated anterior cruciate ligament tear, posterior cruciate ligament tear and medial collateral ligament tear were seen in, 5.55%, 37% and 16.66% cases with 0.001, 0.018 and 0.044 p-values respectively [Table:3] suggesting anterior cruciate ligament tear has strong association compared to posterior cruciate ligament and medial collateral ligament tear which was comparable with study conducted by Sahoo et al., 2016 with 100% anterior cruciate ligament involvement.<sup>10</sup>

### Clip injury

In our study clip injury was second most common mechanism of injury accounting for 25% with road traffic accident being the most common mode of injury with 68% cases and 0.002 p-value followed by sports injury (24% - cases). Significant correlation was found for posterolateral tibial plateau (80%), midportion of lateral femoral condyle (56%), postero-lateral femoral condyle (24%) and medial femoral condyle (72%) marrow edema [Fig - 2] in clip injury. Our results were comparable with article published by Sanders et al., 2000, Sahoo et al., 2016 and Berger et al., 2013 which shows resultant bone marrow contusion pattern at the posterior aspect of the lateral tibial plateau, midportion of the lateral femoral condyle, medial femoral condyle & posterior lip of the medial tibial condyle.<sup>5,10,12</sup> In our study commonly associated soft tissue injuries were anterior cruciate ligament and medial collateral ligament tears. In our study medial collateral ligament tear (80%) was most common associated injury with clip injury followed by anterior cruciate ligament (76%) and posterior cruciate

ligament (44%). P-values for medial collateral ligament tear [Table/Fig-4] was 0.001 which was statistically significant. Our results comparable with study done by sahuo et al., 2016 and berger et al.,2013.<sup>10,12</sup>

#### Dash board injury

In our study dashboard injury is third most common contusion pattern accounting with 7% cases with involvement of patella (6 cases - 85.7%) and anterior most part of tibia as most frequently involved areas [Table:1 & 2] with p-value <0.05 which is comparable with study conducted by Sahoo et al., 2016 and Berger et al., 2013 which shows involvement anterior part of lateral and medial tibial condyle (each 50%) with occasional involvement of posterior surface of patella.<sup>10,12</sup> In our study most common mode of injury was found to be road traffic injury with 100% cases and p value 0.002, which is comparable with the study conducted by Sahoo et al., 2000 and Rodriguez, 2008.<sup>10,13</sup> In both these studies road traffic accident was the most common mode of injury. PCL involvement was showing more significant correlation with dashboard injury [Table:3] and road traffic accident with 0.002 p-Value which is in concordant with study done by Sahoo et al., 2016 and Rodriguez, 2008.<sup>10,13</sup>

#### Hyperextension injury

In present study, hyperextension injury was seen in 7% cases. Kissing contusion due to domestic hyperextension was most common mode followed by 2 cases (28.6%) cases of sports injury- soccer. According to Sahoo et al., 2016 50% cases, Berger et al., 2013 7.1% (16 out of 225) and Terzidis et al.,2004 50% cases were having kissing contusions.<sup>10,12,14</sup> In our study most frequently involved areas were anterior part of tibia involving medial and lateral plateau with anterior portion of both lateral and femoral condyles [Table:1 & 2] which is comparable with study conducted by Sanders et.al, 2000 and Terzidis et al., 2004 with resultant contusion was seen at distal femur or proximal tibia in anterior aspect.<sup>5,14</sup> In our study 50% of kissing contusions cases were associated with anterior cruciate ligament [Table:3] tears which is comparable with study done by sahuo et al. , 2016 and Terzidis et al., 2004 with anterior cruciate ligament being a most commonly involved ligament.<sup>10,14</sup>

#### Lateral patellar shift

In our study lateral patellar shift was seen in 7% cases with anterior & mid part of lateral femoral condyle and medial patella being the most commonly involved areas [Table:1 & 2]. Our study was comparable to study done by Sahoo et al., 2016, Kirsch et al, 1993, Sanders et al, 2000 and Bahr et al., 2005 in which lateral femoral condyle contusion and infero medial patellar involvement was most common areas to be involved in lateral patellar shift injury.<sup>10,15,5,16</sup> In our study most common mode of lateral patellar shift was found to be road traffic accident which is contradictory to study done by Sahoo et al 2015, Sander's et al, 2000 and kirsch et al.,1993 This may be because of more number of road traffic accident cases in our study.<sup>10,5,15</sup> According to study done by Sahoo et al., 2016 associated injury include medial patello-femoral ligament in all (100% cases) and anterior cruciate ligament

in 33% cases which is comparable with our study.<sup>10</sup>

#### CONCLUSION

The study shows precise location of contusion and its pattern on MRI, which reflects mode of injury and allows focused search for associated ligamentous and meniscal tear which may change the further management. According to our study pivot shift injury was most common mechanism of injury and road traffic accident was most common mode of injury.

#### Limitations

Despite being a gold standard modality for diagnosing meniscal tear or associated injuries, knee joint arthroscopy was not included in our study because of its invasive nature. MRI was taken as the gold-standard. A limitation of this study was small number of patients. Large scale studies are needed for generalization of results. Relatively less number of cases of dashboard injury, hyperextension injury and lateral patellar shift injuries were included, so further studies with significant number of these injuries are suggested to overcome these factors.

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