Print ISSN: 2321-6379
Online ISSN: 2321-595X

Original Article

Correlation Between Patterns of Bone Marrow Edema and Their Associated Soft-Tissue Injuries, as seen on Magnetic Resonance Imaging of Knee joint in Patients with a Recent History of Trauma

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Abstract

Introduction: Bone bruise or bone marrow edema is a common innocuous finding in magnetic resonance imaging (MRI) knee of patients with trauma. The pattern of bone marrow edema provides insight into the mechanism of injury which, in turn, helps to evaluate the injuries with a more discerning eye. Five basic mechanisms of knee injury which are commonly seen in MRI scan of knee trauma patients are pivot shift, dashboard injury, hyperextension, clip injury, and lateral patellar dislocation. Each of these mechanisms causes characteristic bone marrow edema patterns and has associated soft-tissue injuries, following the musculoskeletal biomechanics.

Aim: The purpose of this study is to assess the correlation between bone marrow edema patterns and associated soft-tissue injuries.

Settings and Design: This is a cross-sectional study of 200 patients conducted at the Department of Radiodiagnosis and Imaging, MGM Medical College and Associated Hospitals, Indore.

Materials and Methods: MRI of 200 cases of recent knee injury was analyzed to determine bone marrow edema pattern. The pattern of edema and soft-tissue injuries was plotted and analyzed to see a significant correlation.

Statistical Analysis Used: Variables were expressed as percentages and comparison was done by Chi-square analysis. Two-tailed $P < 0.05$ was considered statistically significant.

Results: Significant correlation was seen between pivot shift injury and anterior cruciate ligament (ACL) tear, pivot shift injury and medial meniscus tear, dashboard injury and posterior cruciate ligament (PCL) tear, lateral patellar dislocation and medial patellofemoral ligament (MPFL) tear, and clip injury and medial collateral ligament (MCL) tear. Pivot shift was the most common bone marrow edema pattern, accounting for 55.5% of cases and hyperextension was the least common pattern, seen in only 3% of cases.

Conclusion: The pattern of bone marrow edema can provide a road map to associated soft-tissue injuries which assist in finer evaluation and can help in creating better patient management outcomes.

Key words: Bone bruise, Bone marrow edema, Magnetic resonance imaging knee, Musculoskeletal, Trauma

INTRODUCTION

Knee joint is a major weight-bearing joint of the human body with a wide range of dynamic mobility and is subjected to countless mechanical forces. Smooth functioning of the knee joint relies on many soft-tissue structures to maintain bone alignment and movement. When forces beyond the physiological range act on the joint, these result in bone and soft-tissue injuries.[1]

Bone marrow edema or "bone bruise" depicts the changes in bone secondary to trabecular injury. These are routinely seen in magnetic resonance imaging (MRI) scans of musculoskeletal trauma as areas of decreased signals on T1 images and increased signal on T2, STIR, PD, and fat-saturated images.[2]

Access this article online

www.ijss-sn.com

Month of Submission : 06-2020
Month of Peer Review : 06-2020
Month of Acceptance : 07-2020
Month of Publishing : 07-2020

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Five major mechanisms of knee injuries have been described, which are – pivot shift, clip, dashboard, lateral patellar dislocation, and hyperextension injuries. These mechanisms leave characteristic bone marrow edema patterns following the musculoskeletal biomechanics and hence cause specific associated soft-tissue injuries. This pattern of bone marrow edema is like a "footprint" of mechanism of injury and gives clues regarding the associated soft-tissue injuries.[3]

MATERIALS AND METHODS

This was a hospital-based cross-sectional study done at the Department of Radiodiagnosis and Imaging, Mahatma Gandhi Memorial Medical College and Associated Hospitals, Indore, from October 2019 to April 2020. A total of 200 cases of MRI knee with a recent history of trauma (<4 weeks) were included.

MRI of the affected knee joint was done as per imaging protocol and images were stored in a compact disc. Inclusion criteria were patients of age group 20–45 years with a recent knee injury (<4 weeks). Patients with compound or comminuted fractures, pathological fractures, orthopedic implants, neoplasm of knee joint, old injuries without marrow edema, and those having bone marrow diseases unrelated to trauma were excluded from the study.

MR studies were done by GE Signa Pioneer 3.0 T MR system with a dedicated knee coil. The patient was placed in supine position with the knee slightly externally rotated (10–20°) and sagittal (T1, T2, PD, and PDFS), coronal (STIR/merge), and axial (T2, PDFS) sequences were taken. Imaging was done using FOV: 150 mm, slice thickness of 3 mm on sagittal images; FOV: 150 mm, slice thickness of 3 mm on coronal images; and FOV: 150 mm, slice thickness of 3.5 mm on axial images with interslice gap of 1.5 mm. An axial acquisition through the patellofemoral joint was used as the initial localizer for subsequent coronal and sagittal images. The sagittal plane was primarily used to evaluate the bone marrow edema which was confirmed on coronal images.

MRI was analyzed by two observers to determine bone marrow edema pattern. The edema patterns were distributed into six categories, namely, pivot shift, dashboard, clip, hyperextension, lateral patellar dislocation, and complex or mixed pattern. The pattern of edema and soft-tissue injuries was plotted and analyzed to see any significant correlation.

Statistical Analysis

Data was analyzed using SPSS v 24.0. Variables were expressed as percentages and evaluation of dependence was done by Chi-square analysis. The strength of association was expressed by Phi coefficient (ø). Two-tailed $P < 0.05$ was considered statistically significant for all the tests.

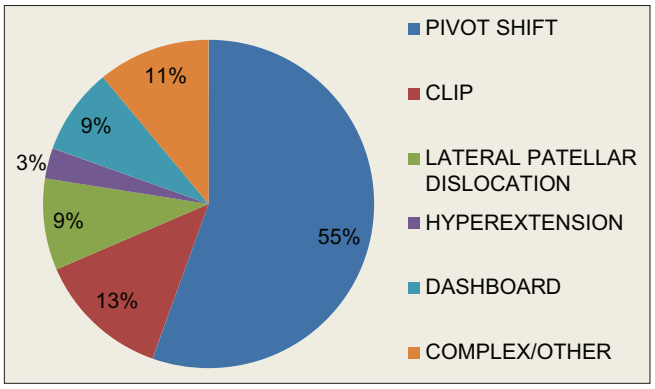
RESULTS

Knee Injury MRI Patterns

The most common pattern of knee injury observed in our study was pivot shift injury, which was seen in 55.5% of cases, followed by clip injury which was seen in 13% of cases. Lateral patellar dislocation and dashboard injuries were seen in 9% and 8.5% of cases, respectively. Hyperextension injury was the least common, accounting for 3% of cases. Nearly 11% of cases had complex bone marrow edema patterns not conforming to a single category and were classified as complex/mixed pattern [Graph 1, Table 1].

Pivot Shift Injury

Significant correlation was observed between pivot shift injury pattern and ACL injury, with ACL tear in 96.4% of cases. Chi-square test revealed $P < 0.001$ and Phi coefficient (ø) of 0.634. Posterior horn of medial meniscus was the second most common soft-tissue injury, seen in 45.9% of cases of pivot shift mechanism ($P < 0.05$) followed by MCL which was injured in 41.4% of cases. Other soft-tissue injuries observed were anterior horn of medial meniscus in 15.3% of cases, anterior horn of lateral meniscus in 6.3%,



Graph 1: Distribution of various types of knee injury patterns. Pivot shift injury was the most common mechanism observed accounting for 55.5% of cases. Hyperextension was the least common mechanism observed in this study, accounting for 3% of cases

Table 1: Distribution of various types of knee injury patterns

Type of injury	Cases	Percentage
Pivot shift	111	55.5
Clip	26	13
Lateral patellar dislocation	18	9
Hyperextension	6	3
Dashboard	17	8.5
Complex/other	22	11
Total	200	

posterior horn of lateral meniscus in 17.1%, and lateral collateral ligament in 12.6% of cases [Graph 2].

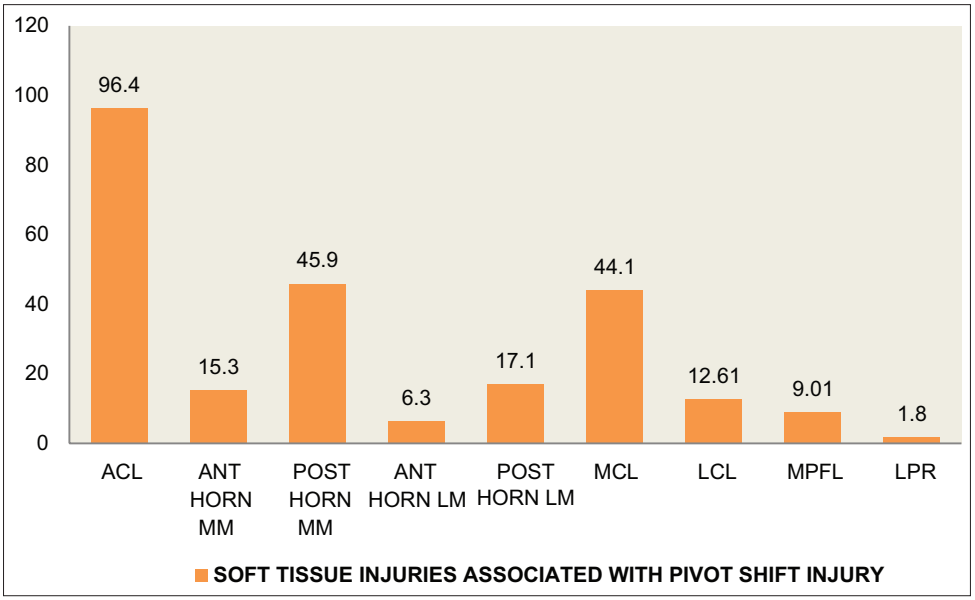
Dashboard Injury

Significant correlation was observed between PCL injury and dashboard pattern of bone marrow edema, with PCL injury in 88.23% of cases. Chi-square test showed $P < 0.001$ and Phi coefficient (ø) of 0.547. In dashboard pattern of bone marrow edema, PCL injury was far more common than ACL injury, which was seen in only 11.76% of cases. Other soft-tissue injuries observed were medial meniscus injury in 17.64% of cases, lateral meniscus injury in 17.64%, and MCL tear in 5.8% of cases [Graph 3].

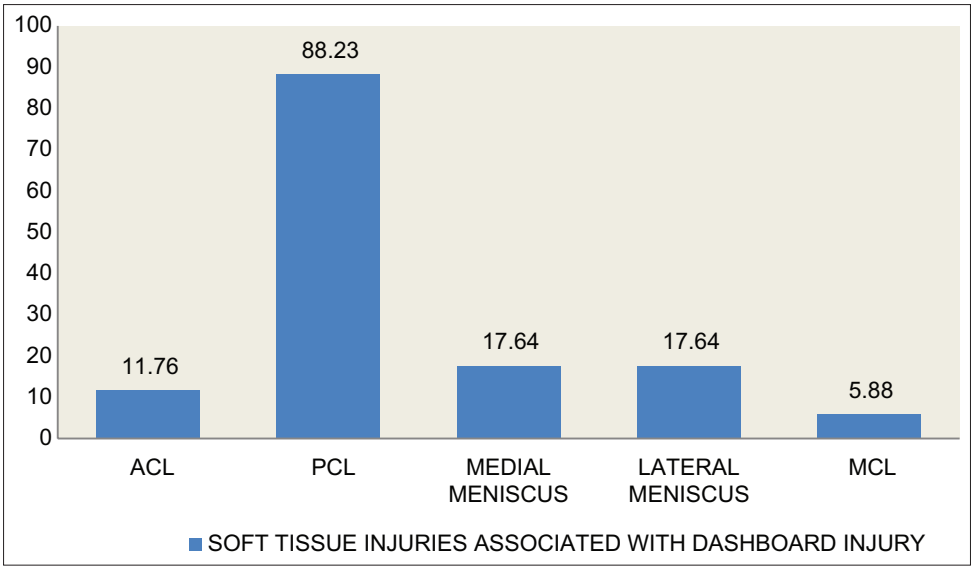
PCL avulsion fracture was more commonly seen in dashboard injury with 57.14% of all PCL avulsion fractures occurring in dashboard injury and 42.84% in other injuries [Graph 4].

Lateral Patellar Dislocation

Significant correlation was observed between medial patellofemoral ligament injury and lateral patellar dislocation pattern, with 94.45% of cases showing medial patellofemoral ligament injury. Chi-square test revealed $P < 0.001$ and Phi coefficient (ø) of 0.648. ACL was another commonly injured soft tissue, seen in 37.5% of cases [Graph 5].



Graph 2: Soft-tissue injuries associated with pivot shift injury. ACL was most common soft tissue to be injured followed by posterior horn of medial meniscus and medial collateral ligament. Pivot shift injury showed significant correlation with ACL injury ($P < 0.001$, ø coefficient of 0.634) and medial meniscus injury ($P < 0.05$)



Graph 3: Soft-tissue injuries associated with dashboard injury. PCL injury was the most common soft-tissue injury associated with dashboard injury ($P < 0.001$, ø coefficient of 0.547). PCL avulsion fracture was more commonly seen in dashboard injury (57.14%) than other types of injuries (42.84%)

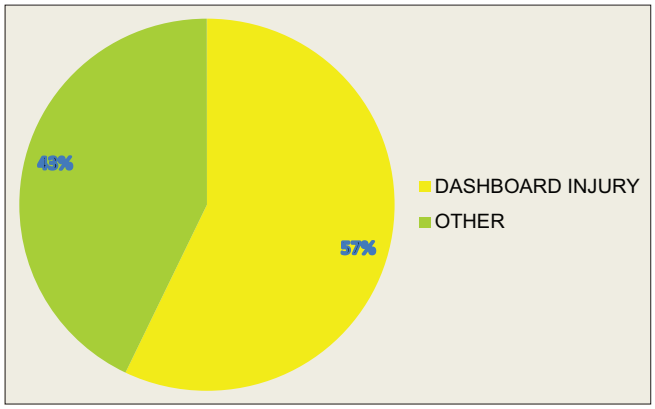
Clip Injury

Significant correlation was seen between MCL injury and clip injury pattern of bone marrow edema with 88.46% of cases having MCL injury. Chi-square test revealed $P < 0.001$ and Phi coefficient (ø) of 0.45. ACL was second most common soft-tissue injured, seen in 61.54% of cases, followed by posterior horn of medial meniscus, seen in 53.84% of cases [Graph 6].

O'Donoghue's triad of ACL, MCL, and medial meniscus injury was seen in 17 (15.3%) cases of pivot shift injury and 5 (19.23%) cases of clip injury.

Hyperextension Injury

In hyperextension injury, ACL and posterior horn of medial meniscus were most common soft-tissues injured, each seen in 50% of cases, followed by MCL injury (33.34%). LCL, PCL, and lateral meniscus injury were seen in 16.67% of cases each [Graph 7].



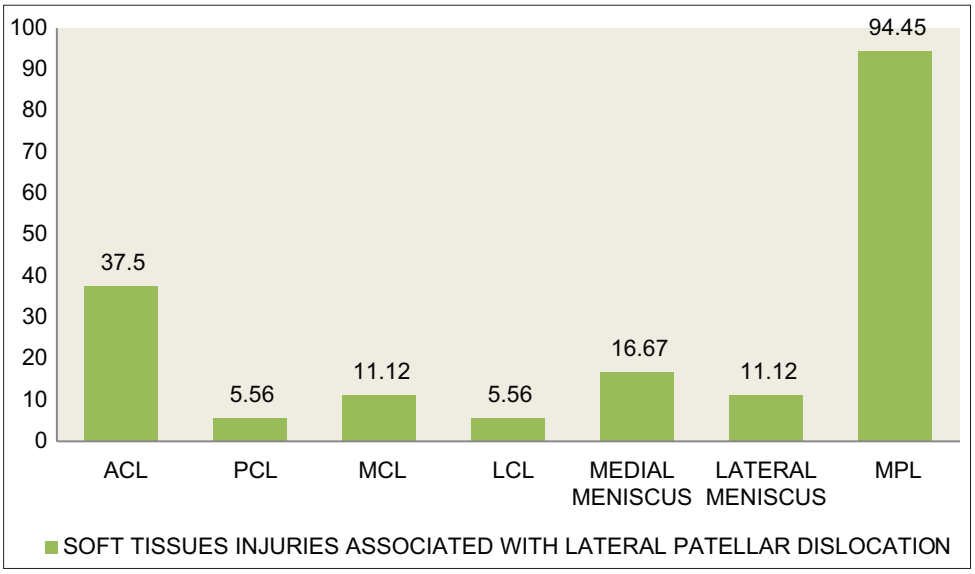
Graph 4: PCL avulsion fracture in dashboard injury compared to other injuries. PCL avulsion fracture was more commonly seen with dashboard injury as compared to other injuries

DISCUSSION

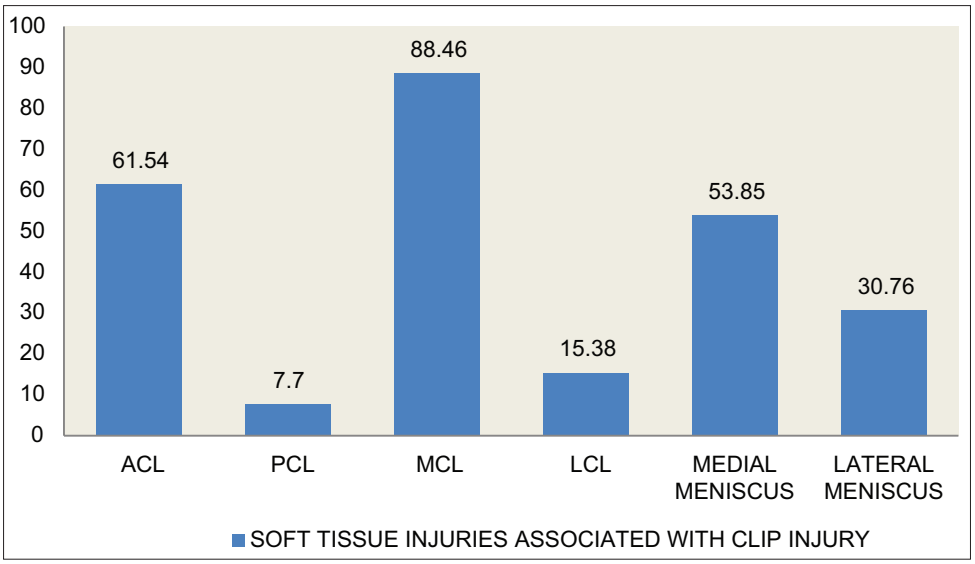
Knee joint is a major weight bearing joint of the human body, and hence prone to injuries, both by direct trauma and indirectly by compressive or tensile forces. While X-ray is the workhorse of musculoskeletal trauma, MRI provides far more extensive insight into the finer aspects of musculoskeletal injury with regard to soft-tissue damage.[4]

Two major types of forces can act on knee joint, compressive, or tensile. When compressive forces act on joint beyond the physiological range, it causes bone marrow contusion and damage to interposed soft tissues. On the contrary, tensile forces pull bones and soft-tissue apart, causing ligament and tendon injuries as well as avulsion fractures. Apart from the type of force involved, important facets determining type of injury are the direction of the force and state of flexion or extension of knee joint at time of injury. All these phenomenon give rise to bone marrow edema patterns which provide a clue to the type of injury.[5]

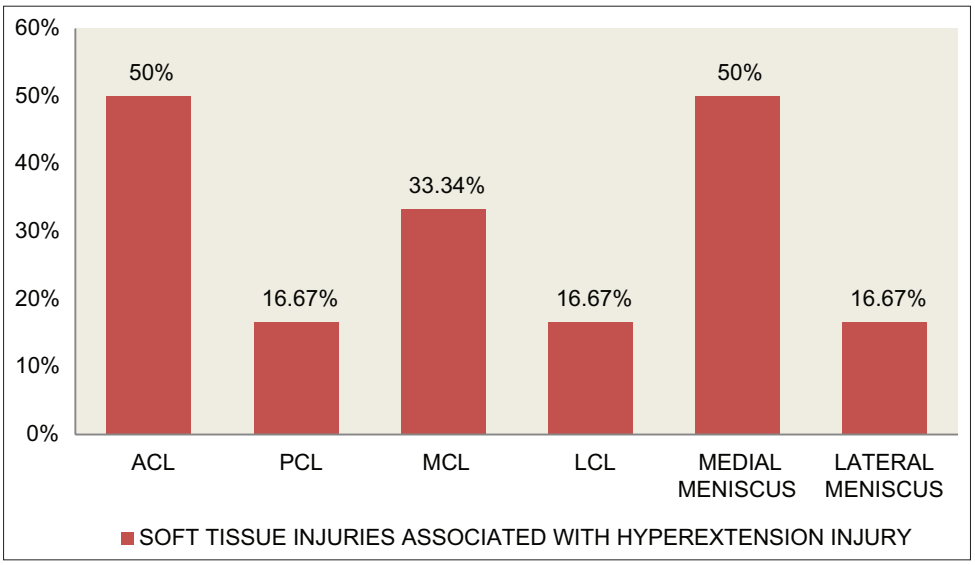
On MR images, trabecular contusion is seen as bone marrow edema. Although bone marrow edema is non-specific and can also be seen in inflammatory and neoplastic disorders, a traumatic cause is usually obvious based on clinical history.[6] Bone marrow contusion



Graph 5: Soft-tissue injuries associated with lateral patellar dislocation. Significant correlation was seen between medial patellofemoral ligament injury and lateral patellar dislocation ($P < 0.001$, ø coefficient of 0.648). ACL was another commonly injured soft tissue (37.5%)



Graph 6: Soft-tissue injuries associated with clip injury. Significant correlation was seen between MCL injury and clip injury pattern of bone marrow edema with 88.46% of cases having MCL injury (*P* < 0.001 and ø 0.45). ACL was the second most common structure injured, seen in 61.54% of cases, followed by posterior horn of medial meniscus, seen in 53.84% of cases



Graph 7: Soft-tissue injuries associated with hyperextension injury. In hyperextension injury, ACL and posterior horn of medial meniscus were most common soft-tissues injured, each seen in 50% of cases followed by MCL injury (33.34%). LCL, PCL, and lateral meniscus injury were seen in 16.67% of cases each

usually resolves in 6–8 weeks. In a study in 2007 by Boks *et al*. on the natural course of bone bruises in post-traumatic knees, they concluded that median healing time of bone bruises is 42.1 weeks.[7] In the present study, the patients having < 4 weeks history of trauma were included.

Many studies have been performed on a mechanism-based pattern to approach of knee injury, due to complex nature of the knee joint and multitude of forces acting on it. In their study on biomechanical approach to MR of acute knee injury in 2011, Macmohan *et al*. concluded that MR findings can reveal traumatic mechanism in many acute knee injuries and may predict subtle important but easily missed abnormalities.[8] In a study of clinical and diagnostic significance of bone marrow edema in 2007, Liu *et al*. concluded that MRI can accurately depict bone marrow edema and its adjunctive soft-tissue injuries.[9]

Hayes *et al*. published a mechanism-based pattern approach to classification of complex knee injuries in 2000, in which they proposed 10 patterns of bone marrow edema based

on direction of force and position of knee joint and their pattern specific soft-tissue injuries, which may help in better assessment of thorough extent of knee injury.[10]

In 2000, Sanders *et al.* described five major mechanisms of knee injury, which are – pivot shift injury, dashboard injury, hyperextension injury, clip injury, and lateral patellar dislocation.[3] By studying the distribution of the edema, one can understand the mechanism of injury that occurred and thereby predict with certain accuracy, certain associated soft-tissue injuries that may be present.

In the present study, pivot shift was the most common mechanism of injury and was seen in 55.5% of cases. This is similar to the study by Sahoo *et al.* (2016) on correlation between bone marrow edema and mechanism of injury, in which pivot shift was most common mechanism observed comprising 56.5% of cases.[11]

Pivot Shift Injury

Pivot shift injury is an indirect injury that occurs when a valgus load is applied to the knee in various states of flexion combined with external rotation of the tibia or internal rotation of the femur.[3] This type of injury usually occurs with maneuvers which involve rapid deceleration and simultaneous direction change and hence is commonly seen in sports injuries and two wheeler accidents.[11] These maneuvers cause tensile forces on anterior cruciate ligament (ACL) and can result in its rupture.[12] Once the ACL is disrupted, anterior subluxation of the tibia relative to the femur occurs, which results in impaction of the lateral femoral condyle against lateral tibial plateau. The resulting bone contusion pattern classically involves the posterolateral tibia and the lateral femoral condyle [Figure 1]. Rarely, medial tibial plateau can also be involved.[13] Following biomechanical pattern of injury, ACL is the most common soft-tissue injured. Other soft-tissues injured are menisci and MCL.[3,8-10]

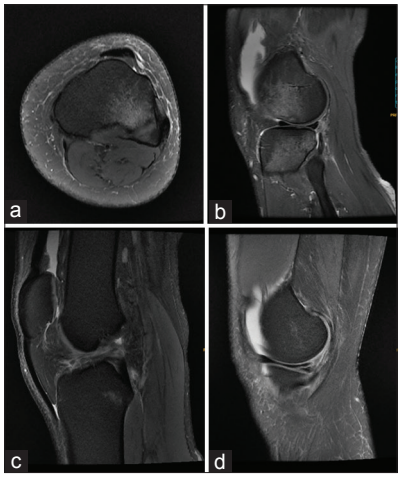


Figure 1: Axial and sagittal PDFS MRI knee images showing (a,b) classical pattern of pivot shift bone marrow edema, involving posterolateral tibia and lateral femoral condyle. (c,d) Complete ACL tear and Grade III tear of posterior horn of medial meniscus in same patient. Mild joint effusion is also present.

In the present study, ACL was the most common soft-tissue injured, which was seen in 96.4% of cases of pivot shift injury, followed by posterior horn of medial meniscus (45.9%) and medial collateral ligament (44.1%). A strong correlation was seen between pivot shift injury and ACL tear ($P < 0.001$, ø 0.634) in our study. Pivot shift injury was also associated with medial meniscus tear ($P < 0.05$).

These results are in keeping with the publication by Sanders *et al.* on bone marrow edema patterns in which they stated that soft-tissues injured in pivot shift include ACL, posterior horn of lateral or medial meniscus, and MCL.[3] A similar publication by Hayes *et al.* on mechanism-based approach to classification of knee injuries also supports these findings.[10] A study by Wei *et al.* on MR diagnosis and clinical significance of bone contusion of knee also showed that the most common soft-tissue injuries associated with pivot shift injury were ACL, medial meniscus, and MCL tears.[9]

Clip Injury

The clip injury is a contact injury which occurs after a pure valgus stress is applied to mildly flexed (<30°) knee.[3,12] It can be sustained during road traffic accidents (e.g., fall from two wheeler) and in sports.[11] The bone marrow edema is usually most prominent in the lateral femoral condyle and lateral tibial plateau as a result of direct blow, whereas a second smaller area of edema may be present in the medial femoral condyle due to tensile stress to the MCL [Figure 2]. Most common associated soft-tissue injury is varying degrees of sprain or disruption of the MCL, mostly near the femoral attachment site.[14] A Grade I sprain of the MCL is visualized on MRI as contour irregularity and edema superficial to the MCL with intact fibers. Grade II injury is a partial tear of the MCL and can be seen on MR images as a partial discontinuity of the fibers with adjacent areas of increased signal intensity on T2-weighted images. Grade III injury is complete disruption of fibers and can be seen as complete discontinuity of the MCL fibers with extensive surrounding high signal intensity on T2-weighted images.[15] Other soft-tissue injuries which can be seen are ACL and medial meniscus tears.[3,9,10]

In the present study, MCL tear was most common soft-tissue injury associated with clip injury and was seen in 88.46% of cases, followed by ACL tear in 61.54% and medial meniscus injury in 53.85% of cases. A strong correlation was seen between clip injury and ACL tear ($P<0.001$, ø 0.45) in our study. These results are in concordance with publications by Sanders *et al.* and Hayes

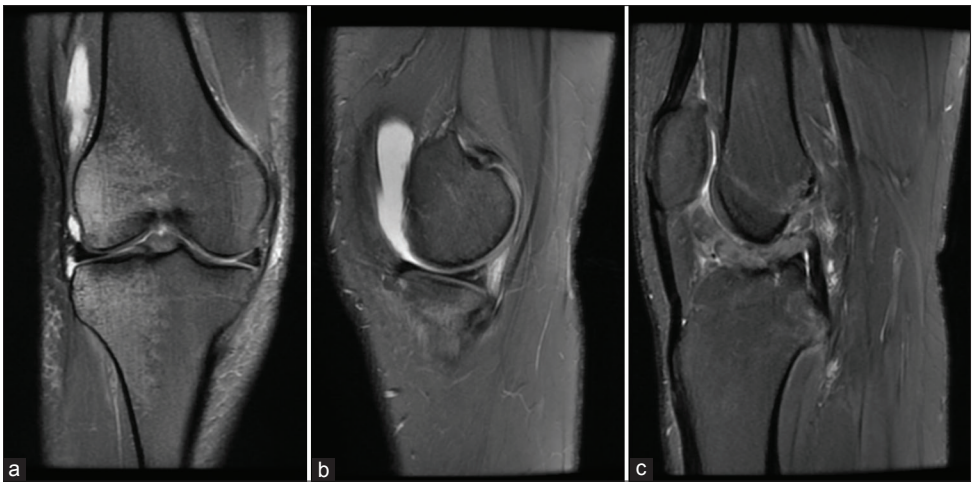


Figure 2: Coronal and sagittal PDFS MR images of knee joint showing (a) clip injury pattern of edema involving lateral femoral condyle and lateral tibial plateau. Grade I sprain of MCL is also seen. (b,c) Grade II tear in posterior horn of medial meniscus and ACL tear in same patient, together forming O'Donoghue's triad. Mild joint effusion is also present.

et al. on bone marrow edema patterns, which state that MCL, medial meniscus (specially posterior horn), and ACL are most common soft-tissues injured in clip injury.[3,10] Liu *et al.* reported MCL tear, ACL tear, and medial meniscus injury as the most common findings in clip injury in their study on clinical and diagnostic significance of bone marrow edema, which concurs with our findings.[9]

Dashboard Injury

Dashboard injury, as the name implies, can be sustained during car accidents where knee is pressed against the dashboard. It can also occur when flexed knee strikes ground during fall.[11] In this type of injury, an anteroposteriorly directed force is applied to a knee in 90° flexion.[12] In this position, PCL is more taut than ACL and hence more prone to injury. Furthermore, PCL is the primary resistance to posterior dislocation of tibia, making it the most commonly injured soft tissue in dashboard injury.[10] It is the only mechanism where PCL is injured more commonly than ACL. Bone marrow edema is classically observed in anterior proximal tibia and rarely on posterior surface of patella [Figure 3].[3]

In the present study, PCL was the most commonly injured soft tissue, seen in 88.23% of cases of dashboard injury. It was far more commonly injured than ACL in dashboard injury (11.76%). A strong correlation was seen between dashboard injury and PCL tear ($P < 0.001$, ø 0.547) in our study. Dashboard injury was also the most common mechanism causing avulsion fracture of PCL in the present study (57.14% of cases).

In publications by Hayes *et al.* and Sanders *et al.* on bone marrow edema patterns, they have stated PCL as the most common soft-tissue injured in dashboard injury, which supports our findings.[3,10] The result of the study by Liu *et al.* showed that PCL was the most commonly injured soft tissue in dashboard injury, which is in agreement with our findings.[9]

Lateral Patellar Dislocation Injury

Patella has a natural tendency to dislocate laterally. It can be further compounded by a shallow trochlear groove and patella alta.[16] Patellar dislocation is usually seen in young adults and athletes.[3] It is non-contact injury caused by twisting of knee. When internal rotation of femur occurs on fixed tibia, quadriceps contraction occurs causing dislocation of patella.[16-18] The classical bone marrow edema is seen on lateral femoral condyle and medial patella [Figure 4]. Distraction forces cause stretching and tear of medial patellofemoral ligament, which is the strongest lateral stabilizer of patella.[16-18]

In the present study, MPFL was the most commonly damaged soft tissue in lateral patellar dislocation, seen in 94.45% of cases. A strong correlation was seen between lateral patellar dislocation and MPFL tear ($P < 0.001$, ø 0.648) in our study. ACL was another commonly injured soft tissue, seen in 37.5% of cases.

In a publication on MR imaging of patellar instability, Diederichs *et al.* stated that MPFL is the most commonly injured soft tissue in lateral patellar dislocation, which supports our findings.[16] Sanders *et al.* have also stated in their publication on pattern of bone marrow edema that medial restraints of knee, especially MPFL is the most frequently injured soft tissues in lateral patellar dislocation.[3]

Hyperextension Injury

Hyperextension injury, as the name suggests, occurs due to hyperextension of knee joint, either directly by an anteriorly directed force on knee with planted foot or indirectly during

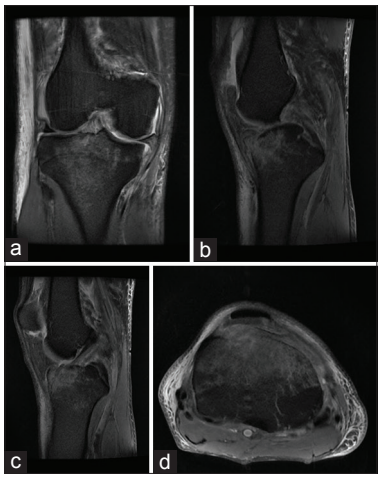


Figure 3: Axial, coronal, and sagittal PDFS MRI knee images showing (a,b,d) classical pattern of bone marrow edema in dashboard injury involving anterior tibia. (b,c) PCL tear is seen, with relatively intact ACL

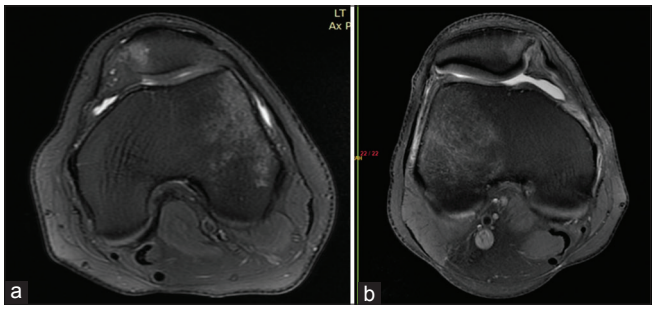


Figure 4: (a) Axial PDFS MR image of knee joint showing classical pattern of bone marrow edema involving medial patella and lateral femoral condyle with wavy medial patellar retinaculum. (b) Axial PDFS MRI knee image of another patient showing bone marrow edema in medial patella and lateral femoral condyle with medial patellar retinaculum and MPFL injury

forceful kicking.[12] The hyperextension of knee results in classical bone marrow edema on anterior tibia and anterior femur, known as "kissing contusions".[3] Rarely, if valgus force is also applied during hyperextension, the kissing contusions can be seen medially [Figure 5]. Associated soft-tissue injuries include tears of cruciate ligaments and menisci. Infrequently, with excessive force, injury to neurovascular bundle and popliteal fossa muscles may also be seen.[3]

In the present study, ACL (50%) and medial meniscus (50%) were most commonly injured structures in hyperextension injury followed by MCL (33.34%) and PCL (16.67%). These results are nearly comparable to the results of study by Liu *et al.,* in which ACL and PCL tears were common injuries in dashboard injury.[9] These findings are also in accordance with publication by Sanders *et al.* on bone marrow edema patterns, in which they have stated that ACL, PCL, and menisci are the most commonly injured soft tissues in hyperextension injury.[3]

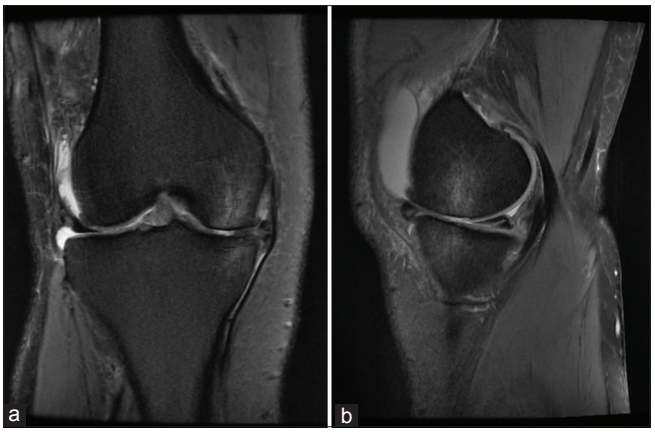


Figure 5: Coronal and sagittal PDFS MRI knee images showing "kissing contusions" on medial femoral condyle and medial tibial plateau in hyperextension injury. Grade II MCL sprain is also seen. (b) Medial meniscus extrusion and Grade II tear of posterior horn of medial meniscus in same patient. Joint effusion is also noted

CONCLUSION

Knee joint is a complex weight-bearing joint and is acted on by a multitude of forces. By studying the patterns of bone marrow edema, one can get an insight on mechanism of injury and predict the associated soft-tissue injuries. This systematic focused analysis can help in achieving a more accurate and rapid interpretation and furthermore create better patient management outcomes.

REFERENCES

1. Shelburne KB, Torry MR, Pandy MG. Muscle, ligament, and joint-contact forces at the knee during walking. Med Sci Sports Exerc 2005;37:1948-56.
2. Kung JW, Yablon CM, Eisenberg RL. Bone marrow signal alteration in the extremities. AJR Am J Roentgenol 2011;196:W492-510.
3. Sanders TG, Medynski MA, Feller JF, Lawhorn KW. Bone contusion patterns of the knee at MR imaging: Footprint of the mechanism of injury. Radiographics 2000;20:S135-51.
4. Lim YS, Peh WC. Magnetic resonance imaging of sports injuries of knee. Ann Acad Med 2008;37:354-61.
5. Ciuffreda P, Lelario M, Milillo P, Vinci R, Coppolino F, Stoppino LP, *et al*. Mechanism of traumatic knee injuries and MR findings. Musculoskelet Surg 2013;97:S127-35.
6. Boks SS, Vroegindeweij D, Koes BW, Bernsen RM, Hunink MG, Bierma-Zeinstra SM. MRI follow-up of posttraumatic bone bruises of the knee in general practice. AJR Am J Roentgenol 2007;189:556-62.
7. Kessler R, Campbell S, Wong D, Mansfield LB. Magnetic resonance imaging of bone marrow: A review-Part II. J Am Osteopath Coll Radiol 2012;1:13-24.
8. MacMahon PJ, Palmer WE. A biomechanical approach to MRI of acute knee injuries. AJR Am J Roentgenol 2011;197:568-77.
9. Wei L, Jun Y, Kangwei S, Zhu C, Zhu Y, Zhai L. The MR diagnosis and clinical significance of bone contusion of knee. Chin J Radiol 2007;41:1319-22.
10. Hayes CW, Brigido MK, Jamadar DA, Tim P. Mechanism-based pattern approach to classification of complex injuries of the knee depicted at MR imaging. Radiographics 2000;20:S121-34.
11. Sahoo K, Garg A, Saha P, Dodia JV, Raj VR, Bhairagond SJ. Study of imaging pattern in bone marrow oedema in MRI in recent knee injuries and its correlation with type of knee injury. J Clin Diagn Res 2016;10:TC06-11.

12. Haaga JR, Dogra VS, Forsting M, Gilkeson RC, Ha HK, Sundaram M. CT and MRI of Whole Body. 6th ed. Amsterdam: Mosby, Elsevier; 2016. p. 2214.
13. Kaplan PA, Gehl RH, Dussault RG, Anderson MW, Diduch DR. Bone contusion of the posterior lip of the medial tibial plateau (contrecoup injury) and associated internal derangements of the knee. Radiology 1999;211:747-53.
14. Naraghi AM, White LM. Imaging of athletic injuries of knee ligaments and menisci: Sports Imaging Series. Radiology 2016;281:23-40.
15. Major NM, Anderson M. Musculoskeletal MRI. 3nd ed. Amsterdam: Mosby, Elsevier; 2019. p. 370.
16. Diederichs G, Issever AS, Scheffler S. MR imaging of patellar instability: Injury patterns and assessment of risk factors. Radiographics 2010;30: 961-8.
17. Krebs C, Tranovich M, Andrews K, Ebraheim N. The medial patellofemoral ligament: Review of the literature. J Orthop 2018;15:596-9.
18. Desio SM, Burks RT, Bachus KN. Soft tissue restraints to lateral patellar translation in the human knee. Am J Sports Med 2016;26:59-6.

How to cite this article: Bhatnagar A, Rathore B. Correlation Between Patterns of Bone Marrow Edema and Their Associated Soft-Tissue Injuries, as seen on Magnetic Resonance Imaging Knee in Patients with a Recent History of Trauma. Int J Sci Stud 2020;8(4):15-23.

Source of Support: Nil, **Conflicts of Interest:** None declared.