

Functional Anatomy and Injury Correlation of the Knee Collateral Ligaments

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Abstract:

Background: The collateral ligaments of the knee, comprising the medial collateral ligament (MCL) and lateral collateral ligament (LCL), are crucial for joint stability by resisting valgus and varus stresses. Injuries to these ligaments are common in sports and trauma, often presenting with variable clinical outcomes depending on the severity and presence of correlated injuries. Understanding the correlation between functional anatomy and injury patterns is essential for accurate diagnosis and appropriate treatment.

Aim: To analyze the functional anatomy and correlate injury patterns of the knee collateral ligaments in a cohort of patients, and to evaluate management strategies and outcomes.

Methods: This retrospective observational study was conducted at Laxmi Chandravanshi Medical College, Bishrampur over a period of two years. A total of 50 patients with documented knee collateral ligament injuries were included. Data on demographics, mechanism of injury, type of ligament involvement, correlated injuries, treatment modality, and outcomes were collected from medical records. Statistical analysis was performed using SPSS version 23.0, with significance set at $p < 0.05$.

Results: The mean age of participants was 32.8 ± 9.4 years, with a male predominance (72%). MCL injuries were most common (60%), followed by LCL (24%) and combined injuries (16%). The predominant mechanism was sports-related trauma (42%) followed by road traffic accidents (36%). Correlated injuries were observed in 30%, with anterior cruciate ligament (ACL) tears being the most frequent (18%). Conservative management was employed in 70% of cases, while 30% underwent surgery. At 6-month follow-up, 76% achieved good functional recovery, with significantly better outcomes in isolated MCL injuries compared to combined injuries ($p = 0.04$).

Conclusion: MCL injuries represent the majority of collateral ligament injuries, primarily affecting young males engaged in sports. Conservative treatment offers favorable outcomes in isolated injuries, whereas surgical intervention is often required for combined injuries.

Recommendations: Early recognition, precise imaging, and patient-specific treatment strategies are essential to optimize recovery. Further multicenter prospective studies with larger sample sizes are recommended to strengthen evidence regarding long-term outcomes.

Keywords: Knee collateral ligaments; Medial collateral ligament; Lateral collateral ligament; Injury patterns; Conservative management

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Introduction

The knee joint's stability is critically dependent on its ligamentous structures, among which the collateral ligaments — the (MCL) and (LCL) — play vital roles in resisting valgus, varus and rotational forces. Recent anatomical and imaging studies have refined our understanding of these ligaments' structural variability, length-change patterns, and their function in different positions of knee flexion [1,2]. Such advances are essential for diagnosing injuries accurately and guiding effective treatment.

Injuries to the knee collateral ligaments are common in sports and high-energy trauma, often causing significant morbidity. For instance, medial collateral ligament complex injuries frequently occur in conjunction with (ACL) ruptures, particularly when there is injury to correlated structures of the medial side such as the deep MCL or the posterior oblique ligament (POL) [3]. The involvement of multiple ligaments or anatomical variants increases the complexity of injury patterns and may influence both stability and outcomes.

Imaging modalities, especially magnetic resonance imaging (MRI), have become indispensable tools for assessing collateral ligament injury. A systematic review of imaging of the MCL has highlighted that modern MRI protocols can delineate the ligament's morphology and injury grade with good reliability, but that there is still variability in how injuries are classified and how imaging findings correlate with functional instability [4]. Similarly, anatomical meta-analyses have studied the popliteofibular ligament and its relationships within the posterolateral corner, underlining the clinical consequences of overlooked injuries in that region [5]. The biomechanical properties of the collateral ligaments — their stiffness, load to failure, and behavior under varied stress conditions — have also been more precisely quantified in recent experimental studies, which bear direct relevance to surgical repair and reconstruction techniques [1,6].

From a therapeutic standpoint, management of collateral ligament injuries ranges from conservative non-operative treatment to surgical reconstruction, depending on injury severity, correlated ligamentous damage, and patient activity level. A systematic review in 2024 showed that combined ACL + MCL reconstruction for grade II or greater MCL injury reduces failure rates compared to non-operative treatment [7]. Studies of multiligament knee injuries emphasize that early recognition of collateral ligament involvement, prompt imaging, and appropriately staged reconstruction are crucial for achieving optimal functional outcomes [8].

Given this background, there remains a need for retrospective analyses correlating functional anatomy with injury patterns in specific populations. Understanding how anatomical variations, mechanisms of injury, and correlated damage affect clinical outcomes helps in tailoring management strategies. The present study aims to describe the functional anatomy of knee collateral ligaments, correlate anatomical and imaging findings with injury types, and analyze outcomes in a cohort of patients seen at a tertiary medical center over a two-year period.

Methodology

Study Design: This study was conducted as a retrospective observational analysis.

Study Setting: The study was carried out at Laxmi Chandravanshi Medical College, Bistrampur, a tertiary care teaching institution catering to a large patient population. The hospital provides advanced diagnostic and surgical facilities, making it an appropriate setting for conducting research on knee injuries.

Study Duration: The study was conducted over a period of 2 years, during which medical records and imaging reports of patients were reviewed and analyzed.

Participants: A total of 50 participants were included in the study based on hospital records. These participants had documented clinical or radiological evidence of knee collateral ligament injury and sufficient medical records available for retrospective analysis.

Inclusion Criteria

- Patients of all genders aged 18 years and above.
- Patients with documented (MCL) or (LCL) injuries.
- Availability of complete medical and imaging records.
- Patients managed either conservatively or surgically within the institution.

Exclusion Criteria

- Patients below 18 years of age.
- Patients with incomplete or missing medical records.
- Cases with isolated injuries to structures other than the knee collateral ligaments.
- Patients with systemic musculoskeletal disorders that may confound analysis.

Bias: To minimize selection bias, consecutive cases fulfilling the inclusion criteria were included in the study. Information bias was reduced by cross-verifying patient details from multiple sources, including case sheets, imaging reports, and operative notes. Observer bias was addressed by involving two independent reviewers to extract and verify data.

Data Collection: Data were collected retrospectively from hospital records, radiological reports, and operative findings. Demographic details, mechanism of injury, type of collateral ligament injury, correlated injuries, treatment modality, and outcomes were recorded in a structured proforma.

Procedure: The collected data were reviewed and categorized according to the type and severity of ligament injury, management strategy, and outcomes. Radiological imaging (X-ray, MRI) reports were correlated with clinical findings to ensure diagnostic accuracy. Patient outcomes were assessed based on available follow-up records.

Statistical Analysis: Data were entered into SPSS version 23.0 for statistical analysis. Descriptive statistics were applied, and results were expressed as mean $\pm$ standard deviation for continuous variables and frequencies/percentages for categorical variables. Comparative analysis was

carried out using chi-square tests for categorical variables and independent t-tests where appropriate. A p-value of <0.05 was considered statistically significant.

Results

A total of 50 patients with knee collateral ligament injuries were included in this retrospective analysis. The mean age of the participants was 32.8 ± 9.4 years (range: 18–55 years). Of the total, 36 (72%) were males and 14 (28%) were females, indicating a male predominance.

Table 1: Demographic Characteristics of Participants (n=50)

Variable	Frequency (n)	Percentage (%)
Age (years)		
18–30	21	42.0
31–40	16	32.0
41–55	13	26.0
Gender		
Male	36	72.0
Female	14	28.0

The majority of participants were young adults (18–40 years), with males being more frequently affected than females.

injuries, 12 (24%) had isolated lateral collateral ligament (LCL) injuries, and 8 (16%) had combined MCL and LCL injuries.

Injury Distribution: Out of the 50 cases, 30 (60%) had isolated medial collateral ligament (MCL)

Table 2: Distribution of Collateral Ligament Injuries

Type of Injury	Frequency (n)	Percentage (%)
Isolated MCL injury	30	60.0
Isolated LCL injury	12	24.0
Combined MCL + LCL injury	8	16.0

MCL injuries were the most common type of collateral ligament injury, accounting for nearly two-thirds of cases.

Mechanism of Injury: The most common mechanism of injury was sports-related trauma (n=21, 42%), followed by road traffic accidents (n=18, 36%), and falls (n=11, 22%).

Table 3: Mechanism of Injury

Mechanism of Injury	Frequency (n)	Percentage (%)
Sports-related	21	42.0
Road traffic accident	18	36.0
Fall	11	22.0

Sports-related trauma emerged as the leading cause of collateral ligament injuries, particularly among young males.

anterior cruciate ligament (ACL) tears (n=9, 18%), meniscal injuries (n=4, 8%), and posterior cruciate ligament (PCL) injuries (n=2, 4%).

Correlated Injuries: Correlated injuries were observed in 15 cases (30%). These included

Table 4: Correlated Injuries with Collateral Ligament Injuries

Correlated Injury	Frequency (n)	Percentage (%)
ACL tear	9	18.0
Meniscal injury	4	8.0
PCL injury	2	4.0
None	35	70.0

Nearly one-third of patients had correlated intra-articular injuries, with ACL tear being the most frequent.

Treatment Modalities: Out of 50 patients, 35 (70%) were managed conservatively with immobilization and physiotherapy, while 15 (30%) underwent surgical repair or reconstruction. Surgical intervention was more common among

patients with combined ligament injuries or severe grades of instability.

Table 5: Treatment Modalities

Treatment Approach	Frequency (n)	Percentage (%)
Conservative	35	70.0
Surgical	15	30.0

Conservative management remained the mainstay, but a significant proportion required surgical intervention for optimal recovery.

Outcomes: At 6-month follow-up (based on available records), good functional recovery was

noted in 38 patients (76%), fair outcome in 8 patients (16%), and poor outcome in 4 patients (8%). Outcomes were significantly better in isolated MCL injuries compared to combined injuries ($p=0.04$).

Table 6: Functional Outcomes at 6-Month Follow-Up

Outcome	Frequency (n)	Percentage (%)
Good	38	76.0
Fair	8	16.0
Poor	4	8.0

The majority of patients achieved good recovery, particularly those with isolated MCL injuries, highlighting the favorable prognosis of this subset.

Discussion

The present retrospective study analyzed 50 cases of knee collateral ligament injuries over a two-year period. The findings showed that the mean age of the participants was around 33 years, with the majority belonging to the young adult group (18–40 years). A clear male predominance (72%) was observed, reflecting their higher participation in sports and outdoor activities, which are major risk factors for such injuries.

Injury distribution revealed that the (MCL) was most frequently involved (60%), followed by (LCL) injuries (24%) and combined injuries (16%). This highlights the anatomical vulnerability of the MCL, particularly due to its role in resisting valgus stress. The leading cause of injury was sports-related trauma (42%), followed by road traffic accidents (36%), which together accounted for nearly four-fifths of all cases, indicating that both high-impact and repetitive stress activities play a significant role in ligament injuries.

Correlated intra-articular injuries were seen in 30% of cases, with (ACL) tears being the most common (18%). This suggests that collateral ligament injuries frequently occur in combination with other ligamentous and meniscal injuries, complicating diagnosis and management.

In terms of management, conservative treatment was the predominant modality (70%), particularly in isolated and less severe cases, while surgical intervention was required in 30%, mainly for combined or severe injuries. At 6-month follow-up, good functional outcomes were achieved in 76% of patients, while 16% had fair and 8% had poor

recovery. Notably, patients with isolated MCL injuries had significantly better outcomes compared to those with combined injuries ($p=0.04$).

The (MCL) is the most frequently injured ligament in the knee and plays a key role in valgus and rotational stability. Anatomy-focused reviews emphasize that the MCL consists of superficial, deep, and posterior oblique fibers, and that detailed knowledge of these structures is critical for clinical decision-making and surgical repair strategies [9,10].

Studies highlight that most MCL injuries heal well with non-operative treatment due to its extra articular location and healing capacity; however, distal tibial-sided ruptures and high-grade injuries often require surgical repair or reconstruction to prevent chronic valgus instability [11,12]. The use of suture augmentation and bioinductive scaffolds (e.g., BioBrace) has been reported to accelerate rehabilitation, reduce laxity, and enhance biological healing [13].

Recent work has refined diagnostic methods, such as the “arthroscopic medial compartment drive-through sign,” which improves accuracy in identifying femoral- versus tibial-sided lesions, guiding precise surgical incisions [14]. Similarly, MRI remains the gold standard imaging modality, not only for injury grading but also for guiding new classification systems that support earlier surgical intervention in severe cases [15,16].

Injury mechanisms are often sport-related, with direct valgus contact being the most common cause. Video analysis of professional athletes confirms that trunk flexion, hip abduction, and slight knee flexion at the time of a lateral blow predispose to isolated MCL rupture [17]. Rehabilitation protocols are central to functional recovery, and comparative analyses suggest that

incorporating kinesiotaping with conventional physiotherapy can shorten recovery duration and enhance knee stability [18]. In surgical practice, advances in minimally invasive reconstruction techniques, including adjustable-loop femoral fixation and posteromedial corner plication, have shown excellent functional outcomes with reduced soft tissue morbidity [19].

Conclusion

Medial collateral ligament injuries were the most common knee collateral ligament injuries, predominantly affecting young males and often resulting from sports-related trauma. While most cases responded well to conservative management with favorable outcomes, combined ligament injuries frequently required surgical intervention and were correlated with poorer prognosis. Early diagnosis and tailored treatment strategies remain essential for optimizing recovery.

References

- Innocenti B, Bori E, Paszicsnyek T. Functional stability: an experimental knee joint cadaveric study on collateral ligaments tension. *Arch Orthop Trauma Surg.* 2022;142(6):1213-20.
- Ball S, Shinohara S, Athwal KK, Williams A, Amis AA. Length-change patterns of the medial collateral ligament and posterior oblique ligament in relation to their function and surgery. *Knee Surg Sports Traumatol Arthrosc.* 2020;28(12):3700-8.
- Bourne M, Sinkler MA, Murphy PB, Colasanti CA, Williams BT, Dornan GJ, et al. Association of medial collateral ligament complex injuries with anterior cruciate ligament ruptures based on posterolateral tibial plateau injuries. *Orthop J Sports Med.* 2023;11(4):23259671231163271.
- Jacobsen JS, Nielsen T, Lind M. Imaging of the medial collateral ligament of the knee: a systematic review. *Knee Surg Sports Traumatol Arthrosc.* 2021;29(2):375-88.
- Pekala PA, Mann MR, Pekala JR, Skinningsrud B, Tomaszewski KA. Evidence-based clinical anatomy of the popliteofibular ligament and its importance in orthopaedic surgery: cadaveric versus MRI meta-analysis and radiological study. *Am J Sports Med.* 2021;49(6):1500-11.
- Nagai T, Sasaki H, Kaneko T, Watanabe K, Yamamoto Y, Sato M, et al. Mechanical properties and characteristics of the anterolateral and collateral ligaments of the knee. *Appl Sci.* 2020;10(18):6266.
- Jackson GR, Kaplan DJ, Mowers CC, Sachdev D, Asif S, Familiari F, et al. Combined ACL and MCL reconstruction results in decreased failure rates compared to non-operative treatment for grade $\geq$ II MCL injuries: a systematic review. *Joints.* 2024;2(2):e842.
- Levy BA, LaPrade RF, Fanelli GC, Wijdicks CA, Stuart MJ. Management of multiligament knee injuries. *EFORT Open Rev.* 2020;5(3):145-55.
- Patel J, Khan W. Collateral ligament injuries in the knee. In: *Sports Medicine and Arthroscopy.* Springer; 2020. p. 375-384.
- Nagai K, Nakanishi Y, Kamada K, Hoshino Y, Kuroda R. Anatomy and biomechanics of the collateral ligaments of the knee. In: *Orthopaedic Biomechanics in Sports Medicine.* Springer; 2021. p. 1-20.
- Trofa DP, Sonnenfeld JJ, Song D, Lynch T. Distal knee medial collateral ligament repair with suture augmentation. *Arthrosc Tech.* 2018;7(9):e921-e926.
- Vosoughi F, Rezaei Dogahe R, Nuri A, Ayati Firoozabadi M, Mortazavi J. Medial collateral ligament injury of the knee: A review on current concept and management. *Arch Bone Jt Surg.* 2021;9(3):255-262.
- LeVasseur MR, Uyeki C, Garvin P, McMillan S, Arciero R. Knee medial collateral ligament augmentation with bioinductive scaffold: surgical technique and indications. *Arthrosc Tech.* 2022;11(3):e583-e589.
- Billières J, Hopper G, Carrozzo A, Ferreira A, Guy S, Vieira T, et al. Arthroscopic medial compartment drive-through sign for knee medial collateral ligament complex injuries. *Arthrosc Tech.* 2022;11(4):e763-e766.
- Wang T. Diagnosis and non-operative treatment of medial collateral ligament. *Proc SPIE.* 2023; 12611:126114D-1-9.
- Makhmalbaf H, Shahpari O. Medial collateral ligament injury; a new classification based on MRI and clinical findings. *Arch Bone Jt Surg.* 2018;6(1):3-7.
- Yüce A, Yerli M, Erkurt N, Mısırlı A, Gürbüz H. Injury mechanism of knee medial collateral ligament: An online systematic video analysis. *J Arthrosc Surg Sports Med.* 2022; 3:1-8.
- Levkov V, Ikonnikova MS, Andronova LB, Remizov AN, Panyukov MV, Butorina A, et al. Comprehensive rehabilitation for injuries to the medial collateral ligament of the knee in skiers and snowkiters. *Med J Russ Fed.* 2022;27(5):473-480.
- Boos AM, Hevesi M, Wang AS, Fiegen AP, Levy BA. Medial collateral ligament reconstruction of the knee: the modified Marx technique with adjustable-loop femoral fixation and posteromedial corner plication. *Arthrosc Tech.* 2023;13(1):1-6.