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Incidence and characteristics of ligamentous knee injuries accompanying a femur shaft fracture and their association with injury mechanism and fracture characteristics: A prospective-observational study in a low-middle-income country

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Abstract

Objective: This study aims to elaborate the incidence, types, and characteristics of ligamentous knee injuries accompanying femoral-shaft fractures and their association with demographic data, fracture characteristics, and injury mechanism.

Methods: This multi-center-prospective-observational study examined patients in the Shaheed Mohtarma Benazir Bhutto Institute of Trauma and Civil Hospital orthopedic wards. Using the consecutive sampling technique, 146 patients with femoral-shaft fractures were recruited, and scrutinized to determine the presence of ligamentous knee injury, through an evaluation form encompassing patients' demographic data, fracture characteristics, knee examinations, and confirmed through magnetic resonance imaging. Knee injuries were detected intra-operatively under regional/general anesthesia and post-operatively utilizing diagnostic maneuvers (varus/valgus stress, Lachman, anterior/posterior drawer, external rotation recurvatum, and McMurray tests) by 2–3 surgeons and confirmed through magnetic resonance imaging. Magnetic resonance imaging was exclusively employed in suspected false positive/negative cases, and when a titanium implant was utilized, that is, 131 cases (89.7%). Chi-square test was used to assess the relationship between incidence and type of ligamentous knee injury with demographic data, injury mechanism, and fracture characteristics.

Results: Among the 146 patients with femoral-shaft fractures, 78% and 22% were males and females, with 37% experiencing associated ligamentous knee injury. Medial collateral ligament and anterior cruciate ligament were the commonest types of ligamentous injuries accompanying femoral-shaft fractures, at 44% and 33%. The Chi-square revealed a statistically significant association between the incidence of ligamentous knee injury accompanying femoral-shaft fracture with demographic data, injury mechanism, and fracture characteristics (p-value < 0.05), and was noted to be higher among males (55.6%), participants aged 18–25 years (66.7%), involved in a road traffic accident (88.9%), resulting in a complex (77.8%) and close fracture (88.9%). A similar association was seen between medial collateral ligament and anterior cruciate ligament injuries with age, injury mechanism, and fracture characteristics (p-value < 0.05).

Conclusion: Our study revealed the unaddressed fact that Pakistan has a significant incidence of ligamentous knee injuries accompanying femoral-shaft fractures. These insights can empower clinicians/surgeons to understand and manage this condition effectively.

Keywords

Incidence, characteristics, association, femur shaft fracture, concomitant knee injury, ligamentous knee injury, low-middle-income country

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Introduction

In trauma patients, the incidence of femoral shaft fractures worldwide varies between 10 and 21 per 100,000 per year.[1–3] Typically, a femoral shaft fracture is a high-impact injury, which is the primary cause of fractures in all population ages and is, therefore, likely to be accompanied by damage to neighboring joints.[4] The literature demonstrates that 5%–35% of patients with femoral fractures often experience concurrent leg injuries.[4–7] Most studies have described ligamentous damage,[4–11] while some have studied concomitant meniscal injuries.[5,8,12] Since a doctor's focus is typically on the initial apparent injury, these secondary injuries are often overlooked during the initial treatment,[5,8] and knee injuries are often overlooked due to the excruciating pain and deformity caused by a femoral shaft fracture.[12] Missed and neglected knee injuries in conjunction with femoral shaft fractures, for example, at rates of 25.5% and 40%,[12,13] can lead to preventable sequelae such as instability or post-traumatic osteoarthritis, significantly affecting a patient's quality of life.[14,15] While a substantial body of literature exists concerning the incidence and characteristics of concurrent knee and femoral injuries, most of these findings are confined to high-income countries and date back decades.[5,9,10,13,16–18] In contrast, data pertaining to low-middle-income economies like Pakistan[19] and data from the most recent years are scarce. Based on the vast range of incidences and the varying characteristics documented in the literature, comprehensive evidence seems still lacking. Therefore, we aimed to investigate the incidence and characteristics of ligamentous knee injury accompanying femoral shaft fractures, along with the association of ligamentous knee injury incidence and its type with demographic data, fracture characteristics, and mechanism of injury, through a multi-center study in Pakistan, and in doing so endeavors to furnish exhaustive and contemporary evidence pivotal for informing efficacious knowledge regarding the incidence and characteristics of ligamentous knee injuries accompanying femoral shaft fractures in low-middle-income country. The focus lies specifically on the unique landscape of low-middle-income countries, highlighting the distinctive nature of this issue and its escalating prevalence, which emerged prominently during increased routine admissions of patients with such conditions, thus prompting the initiation of this study. This initiative represents a departure from existing observations in middle to high-income countries.[5,9,10,13,16–18]

Methods

Study setting, design, and period

We conducted a multi-center prospective-observational study on patients admitted to the orthopedic ward of the Shaheed Mohtarma Benazir Bhutto Institute of Trauma (SMBBIT) and Civil Hospital from 1 January 2022 to 1 February 2023. Ethical approval was obtained from the SMBBIT Institutional Review Board (Ref.#: ERC-000035/SMBBIT/Approval/2021), applicable to both participating institutes. These institutes were chosen for their status as the busiest orthopedic and trauma centers in Karachi, accommodating patients from diverse demographics who sought treatment for fractures and accidents. This study adhered to the latest version of the Declaration of Helsinki on human subject research.

Sample size and sampling techniques

A sample size of 32 was calculated using the open epi sample size calculator $\{n=(Z\^{}2\ P(1-P))/d\^{}2\}$ (where P = incidence, d = margin of error, and Z = constant value from the standard normal distribution corresponding to a 95% confidence interval), by considering 0.021% prevalence of femoral shaft fracture,[1–3] a 5% margin of error, and a 95% confidence interval. We employed a non-probability consecutive sampling technique due to the easy availability of the target population from the two busiest trauma and orthopedic institutes in Karachi, Pakistan. The resultant dataset comprised 146 patients, a cohort deemed having sufficient statistical power to discern significant outcomes within the designated temporal confines of the data acquisition period.

Inclusion and exclusion criteria

Patients with open or closed diaphyseal femoral fracture, ipsilateral or bilateral (inclusive of polytrauma), ranging in age from 18 to 80 years, and having no previous history of a knee injury, who presented to the SMBBIT and Civil Hospital, Karachi, Pakistan, were included in the study. Patients admitted to institutes other than SMBBIT or Civil Hospital and with an intra-articular knee fracture, those with metabolic bone diseases such as osteoporosis, atypical femoral fractures, and pathologic fractures were identified through medical history, clinical assessment, physical examination, laboratory tests (serum calcium and phosphate, vitamin D, parathyroid hormone, alkaline phosphatase, markers of bone turnover, and renal function tests), X-ray, Dual-Energy X-ray Absorptiometry (DEXA) scan, and the fracture risk assessment tool were excluded.

Study tool and data collection procedure

The authors constructed a modified, self-administered version of the evaluation form with the help of the Meybodi et al.[5] study, which was employed with a consent form (Supplemental Files 1 and 2). The evaluation form consisted of three sections. Part I consisted of demographic data of the patients; Part II consisted of fracture characteristics; and Part III consisted of knee examination tests to identify knee injuries. The authors collected the data when patients were admitted to the orthopedic ward of SMBBIT and Civil Hospital, Karachi, Pakistan. The study started with verbal consent outlining the aim of the study and a signature on a written consent form. The characteristics of the fracture were identified through Anteroposterior (AP) and lateral X-rays of the femur. After intramedullary rod implantation and external or plate fixation of the femur, all patients had a comprehensive physical evaluation of the affected limb to identify the suspected knee injuries under general or regional anesthesia, which included the Varus and Valgus stress tests, the Lachman test, the anterior and posterior drawer test, the pivot shift test and the reverse pivot shift test, the external rotation recurvatum test, and the McMurray test, as well as post-operatively during the visit, to observe any difference in findings, which were also confirmed by using magnetic resonance imaging (MRI) in all patients having titanium implants. The valgus and varus stress tests were performed with the knee fully extended and flexed 30° on a supine patient, and at the joint line, the examiner pressed one palm against the lateral and medial aspects of the patient's knee, respectively.[5] The Lachman test was performed with the patient lying supine and the knee was flexed 15° with external rotation. The tibia was moved forward while the femur was stabilized with one hand, and the presence of a mushy or soft terminus deemed the test positive.[5] In the anterior and posterior drawer tests, the patient is supine, and hip and knee are flexed to 45° and 90° respectively, while their feet are placed flat on the table. The tibia is grasped with the hands and pulled anteriorly or pushed posteriorly relative to the femur, and the test is considered positive when the tibia moves more than 5–6 mm forward or backward on the femur.[5] The pivot test was performed with the patient supine and their legs relaxed. The heel of the affected leg is grasped with the opposite hand placed laterally on the proximal tibia distal to the knee. While flexing the knee from a fully extended position, the examiner adds valgus tension and axial load while internally rotating the tibia. A positive test shows that the tibia is out of place while the femur rotates outward, and then the tibia goes back into place at 30° to 40° of flexion.[20] The reverse pivot shift test is performed with the knee flexed between 80° and 90°, and a valgus and external rotation pressure were administered. For a positive test result, the tibia must be subluxated postero-laterally in this position. The knee is extended subsequently.[21] The external rotation recurvatum test is performed with the patient supine, a supra-patellar force is administered, and the great toe is utilized to elevate and externally rotate the tibia. Compared to the uninvolved limb, excessive hyperextension indicates a positive test.[22] The McMurray test is administered with the patient supine and at ease. Then, the patient's heel is held with one hand and the knee's joint line with the other. The knee is maximally flexed, with either external (medial meniscus) or internal (lateral meniscus) tibial rotation. The knee is entirely extended while retaining rotation. A positive test will result in a pop or click.[23] The above tests conclude the following suspected knee injuries: varus stress test = lateral cruciate ligament (LCL), valgus stress test = medial cruciate ligament (MCL), Lachman test/anterior drawer/pivot shift test = anterior cruciate ligament (ACL), posterior drawer test/reverse pivot shift test = posterior cruciate ligament (PCL), the external rotation recurvatum test = ACL and PCL, and the McMurray test = meniscus. For ACL and MCL, one standard test, that is, Lachman and posterior drawer tests, was deemed enough for diagnosis, but other tests were performed not to miss these injuries not diagnosed with the above standard test and to check the extent of the injury. The sensitivity and specificity of clinical tests are as follows: Lachman Test: 80%–95%, 80%–95%; Anterior Drawer Test: 80%–95%, 80%–95%; Pivot Shift Test: 60%–90%, 80%–95%; Posterior Drawer Test: 70%–95%, 80%–95%; Reverse pivot shift test: 26%, 95%[24,25]; McMurray test: 16%–70%, 59%–97%[26]; external rotation recurvatum test: 30%, 100%[27]; valgus stress test: 67%–78%, 49%–91%[28]; varus stress test: 25%.[29] Two to three competent orthopedic surgeons (specialists) performed all clinical evaluations, and authors cross-referenced their findings to reduce inter-observer variability and confirmation bias. The inter-observer reliability rate was measured to be $\kappa = 0.79$ (Cohen's Kappa). MRI imaging was employed in instances where false positives/negatives were suspected (Table 1), and the implant material utilized was titanium, which was 131 cases from 146 patients included (89.7%), to confirm the diagnosis. The rate of false positives and negatives was around 1%–3%, based on examiners/surgeon agreement and disagreement, confirmed through MRI.

Instrument validity

The instrument utilized is a slightly modified version from Meybodi et al.[5] study, which was already validated for its relevance and validity. The instrument was further examined by three members of the SMBBIT IRB committee in Karachi-Pakistan, to ensure its validity and relevance. A pilot study was conducted on ten patients (19%) with femoral shaft fractures to assess the study's validity, relevance, and significance. The analysis also included patients from the pilot study.

Statistical analysis procedure

Data was inputted into an Excel spreadsheet before being imported into Statistical Package for the Social Sciences (SPSS) version 23 for analysis. Descriptive statistics are presented for the demographic data of patients, characteristics of fractures, incidence, types, and characteristics of ligamentous knee injuries. Chi-square test is used to evaluate the association of an incidence of ligamentous knee injury with demographic data, mechanisms of injury, characteristics of fractures, and the association of its type with mechanisms of injury and type of fracture. A p-value of <0.05 was considered statistically significant.

Ethical consideration

The study was performed confidentially, and only the investigators had access to participants' information.

Table 1. Suspected false positives and negative criteria.

Variables	False negative
Varus stress test (LCL)	*False Negative*: A false negative might occur if the patient is not relaxed during the test, muscle spasm restricts joint movement, or if the examiner applies insufficient force. Additionally, chronic LCL laxity may not be well detected in some cases *False Positive*: If the examiner applies excessive force or the joint is hypermobile due to other factors (e.g., generalized ligament laxity), it can lead to a false positive result
Valgus stress test (MCL)	*False Negative*: Similar to the varus test, false negatives may occur due to muscle guarding, patient apprehension, or inadequate force applied by the examiner *False Positive*: Overly forceful valgus stress or hypermobility in the joint can result in false positive findings
Lachman test/ Anterior drawer/ Pivot shift test (ACL)	*False Negative*: In the case of acute ACL injuries, a false negative might occur if the test is performed immediately after the injury when swelling and muscle guarding are significant. In chronic ACL laxity, the test might not be as reliable *False Positive*: If the examiner misinterprets muscle guarding or co-contraction as a positive test, it could lead to a false positive result
Posterior drawer test/Reverse pivot shift test (PCL)	*False Negative*: False negatives can occur if the patient is unable to relax, if the test is not performed correctly, or if other knee structures (e.g., hamstring muscles) compensate for PCL laxity *False Positive*: If the examiner applies excessive posterior force or misinterprets muscle tension as PCL laxity, it can result in a false positive
External rotation recurvatum test (ACL and PCL)	*False Negative*: This test assesses combined ACL and PCL laxity. False negatives can occur if the examiner does not control the tibia's rotation adequately or if the patient has associated joint hypermobility *False Positive*: If the examiner applies excessive external rotation force or misinterprets muscle resistance as ligament laxity, it can lead to a false positive
McMurray test (Meniscus)	*False Negative*: False negatives may occur if the test is not performed properly or if the meniscal tear is in an atypical location not easily provoked by the test's movements *False Positive*: Overinterpretation of joint sounds or pain can lead to false positives. Additionally, other knee pathologies, such as ligament injuries or arthritis, may mimic meniscal symptoms

Reporting of the study

The study's reporting complies with the STROBE guidelines (Supplemental File 3).[30]

Results

Demographic data and characteristics of femur shaft fracture

Among the 146 individuals who had femoral shaft fractures, 78.1% ($n=114$) were male, while 21.9% ($n=32$) were female. Notably, the majority of participants (62.3%; $n=91$) fell within the age range of 18–25, followed by 26–50 (28.1%; $n=41$), and lastly, 51 and above (9.6%; $n=14$). The characteristics of the femoral shaft fractures of the participants are given in Table 2.

Incidence and characteristics of ligamentous knee injury and its association with demographic, trauma mechanism, and femur fracture characteristics

Out of 146 participants, $n=54$ (37%) had ligamentous knee injuries accompanying the femoral shaft fractures. It is worth noting that clinical tests identified suspected ligamentous knee injuries in all cases, with MRI diagnoses confirmation being performed in 49 patients with titanium implants, while the remaining six cases were diagnosed based on clinical tests. The characteristics of the ligamentous knee injuries accompanying femoral shaft fractures of the participants are given in Table 3. The proportion of ligamentous knee injury accompanying a femoral shaft fracture was higher among males, participants aged 18–25 years, involved in a road traffic accident (RTA), resulting in a complex and close fracture type, with the majority being treated with an intramedullary or inter-locking nail. The Chi-square test reveals a statistically significant association of incidence of knee injury with demographic data, mechanism of injury, and fracture features (p-value < 0.05) regarding the proportion of participants with ligamentous knee injuries accompanying a femoral shaft fracture (Table 3).

Type of ligamentous knee injury and its association with demographic, trauma mechanism, and fracture characteristics

Among the 54 participants (37%) with a ligamentous knee injury accompanying a femoral shaft fracture, 24 (44.4%) had an MCL, and 18 (33.3%) had an ACL injury, followed by an LCL injury in 12 (22.2%) patients. The Chi-square test reveals a statistically significant association of the type of ligamentous knee injury with demographic data, mechanism

Table 2. Characteristics of the participants' femoral shaft fractures (*N* = 146).

Variables	Frequency (*n*)	Percentage (%)
Mechanism of injury		
RTA	122	83.5
Fall ground level	8	5.5
Fall from height	8	5.5
Sports/Athletic injury	2	1.4
Gunshot injury	2	1.4
Fall of heavy object on thigh/body	4	2.7
Type of fracture based on appearance of fracture		
Simple	63	43.2
Wedge	33	22.6
Complex	50	34.2
Type of fracture based on appearance of wound		
Open	6	4.7
Close	122	95.3
Classification of a fracture (AO)		
Simple transverse (32-A1)	36	24.7
Simple oblique (32-A2)	23	15.8
Simple spiral (32-A3)	4	2.7
Spiral wedge (32-B1)	7	4.8
Bending wedge (32-B2)	12	8.2
Fragmented wedge (32-B3)	14	9.6
Complex spiral (32-C1)	6	4
Complex intact segmental (32-C2)	8	5.5
Complex comminuted segmental (32-C2)	14	9.6
Complex irregular (32-C3)	22	15.1
Procedure performed		
ORIF	30	20.6
IM/IL nail	110	75.3
External fixator	6	4.1

RTA: road traffic accident; AO: Arbeitsgemeinschaft für Osteosynthesefragen classification; ORIF: open reduction and internal fixation; IM/IL: intramedullary/intramedullary locking.

of injury, and fracture features (p-value < 0.05) regarding the proportion of participants with ligamentous knee injuries accompanying a femoral shaft fracture. The highest association was found to be with MCL injury, followed by ACL and LCL injury (Table 4). The absence of PCL injuries, meniscal injuries, and injuries involving multiple ligaments within the knee joint was observed.

Discussion

This study strives to illuminate the incidence and characteristics of ligamentous knee injury accompanying femoral shaft fractures, along with the association of the incidence and types of knee injury with demographic data, fracture characteristics and the mechanism of injury in a low-middle-income country through a multi-center study. Our findings indicate that 37% of patients with femoral shaft fractures in our study had associated ligamentous knee injuries. In contrast, studies conducted by Byun et al.[4] in Korea, Caldas et al.[6] in Brazil, Walling et al.,[10] and a review by Bandeira et al.[11] found that 20.3%, 30.5%, 33%, and 22.5% of patients with femoral shaft fractures had associated ligamentous knee injuries. Our research has yielded noteworthy results of considerable scientific importance. Prior investigations into the incidence of ligamentous knee injuries had hitherto reported a maximum occurrence rate of 33%. However, our current study has unveiled an unprecedented incidence of ligamentous knee injuries, surpassing any previous records. This finding assumes particular significance in light of the expansive demographic of individuals residing in low- to middle-income countries. The notable difference in our results can be attributed to the unique circumstances of our study location in Pakistan, a low-middle-income country, where accidents resulting in a large number of injuries are frequent. In contrast, the above-mentioned studies were from middle-to-high-income economies of the world. This distinctive milieu underscores the critical role of environmental and socio-economic factors in shaping the epidemiology of ligamentous knee injuries accompanying femur shaft fractures.

Table 3. Characteristics of ligamentous knee injury along with their association with demographic, mechanism of trauma, and fracture characteristics of the patients ($N = 146$).

Variables	Knee injury *n* (%)		*p*-Value (Chi-square)
	Yes	No	
Gender			
Male	30 (55.6%)	84 (91.3%)	0.000 (25.410)*
Female	24 (44.4%)	8 (8.7%)	
Age			
18–25 years	36 (66.7%)	55 (59.8%)	0.009 (9.318)*
26–50 years	18 (33.3%)	23 (25%)	
51 years and above	0 (0%)	14 (15.2%)	
Mechanism of injury			
RTA	48 (88.9%)	74 (80.4%)	0.012 (14.642)*
Fall ground level	0 (0%)	8 (8.7%)	
Fall from height	6 (11.1%)	2 (2.2%)	
Sports/Athletic injury	0 (0%)	2 (2.2%)	
Gunshot injury	0 (0%)	2 (2.2%)	
Fall of heavy object on thigh/body	0 (0%)	4 (4.3%)	
Type of fracture based on appearance of fracture			
Simple	6 (11.1%)	57 (62.0%)	0.000 (72.811)*
Wedge	6 (11.1%)	27 (29.3%)	
Complex	42 (77.8%)	8 (8.7%)	
Type of fracture based on appearance of wound			
Open	6 (11.1%)	2 (2.2%)	0.022 (5.248)*
Close	48 (88.9%)	90 (97.8%)	
Classification of a fracture (AO)			
Simple transverse (32-A1)	0 (0.0%)	36 (39.1%)	0.000 (84.427)*
Simple oblique (32-A2)	6 (11.1%)	17 (18.5%)	
Simple spiral (32-A3)	0 (0.0%)	4 (4.3%)	
Spiral wedge (32-B1)	0 (0.0%)	7 (7.6%)	
Bending wedge (32-B2)	0 (0.0%)	12 (13.1%)	
Fragmented wedge (32-B3)	6 (11.1%)	8 (8.7%)	
Complex spiral (32-C1)	6 (11.1%)	0 (0.0%)	
Complex intact segmental (32-C2)	6 (11.1%)	2 (2.2%)	
Complex comminuted segmental (32-C2)	12 (22.3%)	2 (2.2%)	
Complex irregular (32-C3)	18 (33.3%)	4 (4.3%)	
Procedure performed			
ORIF	0 (0.0%)	30 (32.6%)	0.000 (29.918)*
IM/IL nail	48 (88.9%)	62 (67.4%)	
External fixator	6 (11.1%)	0 (0.0%)	

RTA: road traffic accident; AO: Arbeitsgemeinschaft für Osteosynthesefragen classification; ORIF: open reduction and internal fixation; IM/IL: intramedullary/intramedullary locking.
*Significant association through significant *P*-values.

A pivotal finding derived from our investigation pertains to the incidence of ligamentous knee injuries in conjunction with femur shaft fractures. In our study cohort, it was ascertained that 89% of these injuries were directly linked to RTA. In contrast, investigations conducted by Byun et al.[4] and Walker et al.[13] also identified RTAs as a noteworthy contributor to ligamentous knee injuries; however, it is important that these studies, conducted in higher-income countries, reported a markedly lower incidence of RTA-related injuries, not exceeding 25%. This discrepancy can be explained by the historically higher prevalence of RTAs in low-middle-income economies.[31] RTAs constitute a significant etiological factor in the occurrence of ligamentous knee injuries worldwide, and the reason for it is highlighted by Walker et al.,[13] that the application of force during such accidents, primarily directed longitudinally or transversely along the femur, may result in hyperextension of the knee joint, thereby predisposing individuals to ligamentous damage. This underscores the paramount importance of promptly recognizing and managing knee ligament injuries in RTA casualties, with a view to enhancing therapeutic efficacy and prognostic outlook.

Table 4. Association of types of ligamentous knee injury with demographic, mechanism of trauma, and fracture characteristics of the patients ($N=54$).

Variables	Type of knee injury *n* (%)			*p*-Value (Chi-square)
	LCL	MCL	ACL	
Gender				
Male	6 (11.1%)	12 (22.2%)	12 (22.2%)	0.509 (1.350)
Female	6 (11.1%)	12 (22.2%)	6 (11.1%)	
Age				
18–25 years	6 (11.1%)	12 (22.2%)	18 (33.3%)	0.001 (13.500)*
26–50 years	6 (11.1%)	12 (22.2%)	0 (0%)	
51 years and above	0 (0%)	0 (0%)	0 (0%)	
Mechanism of injury				
RTA	6 (11.1%)	24 (44.4%)	18 (33.3%)	0.000 (23.625)*
Fall ground level	0 (0%)	0 (0%)	0 (0%)	
Fall from height	6 (11.1%)	0 (0%)	0 (0%)	
Sports/Athletic injury	0 (0%)	0 (0%)	0 (0%)	
Gunshot injury	0 (0%)	0 (0%)	0 (0%)	
Fall of heavy object on thigh/body	0 (0%)	0 (0%)	0 (0%)	
Type of fracture based on appearance of fracture				
Simple	0 (0%)	6 (11.1%)	0 (0%)	0.001 (19.286)*
Wedge	0 (0%)	6 (11.1%)	0 (0%)	
Complex	12 (22.2%)	12 (22.2%)	18 (33.3%)	
Type of fracture based on appearance of wound				
Open	0 (0%)	0 (0%)	6 (11.1%)	0.001 (13.500)*
Close	12 (22.2%)	24 (44.4%)	12 (22.2%)	
Classification of a fracture (AO)				
Simple Oblique (32-A2)	0 (0.0%)	6 (11.1%)	0 (0.0%)	0.000 (55.500)*
Fragmented wedge (32-B3)	0 (0.0%)	6 (11.1%)	0 (0.0%)	
Complex spiral (32-C1)	0 (0.0%)	6 (11.1%)	0 (0.0%)	
Complex intact segmental (32-C2)	0 (0.0%)	6 (11.1%)	0 (0.0%)	
Complex comminuted segmental (32-C2)	6 (11.1%)	0 (0.0%)	6 (11.1%)	
Complex irregular (32-C3)	6 (11.1%)	0 (0.0%)	12 (22.2%)	
Procedure performed				
ORIF	0 (0.0%)	0 (0%)	0 (0%)	0.001 (13.500)*
IM IL nail	12 (22.2%)	24 (44.4%)	12 (22.2%)	
External fixator	0 (0%)	0 (0.0%)	6 (11.1%)	

MCL: medial collateral ligament; ACL: anterior cruciate ligament; LCL: lateral collateral ligament; RTA: road traffic accident; AO: Arbeitsgemeinschaft für Osteosynthesefragen classification; ORIF: open reduction and internal fixation; IM/IL: intramedullary/intramedullary locking.
*Significant association through significant *P*-values.

Our study uncovered a higher association of ligamentous knee injuries in conjunction with femur shaft fractures among males (55.6%). This observation aligns with the findings by Byun et al.,[4] who discovered that males (35.3%) exhibited a greater incidence of these injuries than females. The higher representation of male patients in our study can be attributed to the fact that the aforementioned study included 20% of participants aged over 60 years. Even minor impacts can lead to fractures or knee injuries in older age groups due to various factors associated with bone conditions.[4,32] In contrast to the previously mentioned study, our research had a distinct age distribution. Two-thirds of our cohort consisted of individuals aged 18–25 years, while the remaining third belonged to the 26–50-year age group, experiencing ligamentous knee injuries in conjunction with femoral shaft fractures. This suggests that ligamentous knee injuries were more prevalent among younger males. This higher prevalence among younger males or males in general across all age groups can be attributed to their increased involvement in high-energy trauma, such as traffic accidents, which significantly elevates the likelihood of sustaining knee injuries in conjunction with femoral shaft fractures.[4,5] Our results underscore the importance of considering both gender and age groups in understanding this association. These findings provide valuable new insights into the relationship between gender and age groups with knee ligamentous injuries in low-middle-income countries, a dimension that has been underemphasized in previous research.

In our study, a noteworthy discovery was the predominant occurrence of knee ligamentous injuries accompanying femoral shaft fractures, specifically in cases classified as close (88.9%) and complex (77.8%) fractures. In contrast, a study by Byun et al.[4] reported a higher prevalence of wedge fractures. These divergent findings likely stem from variations in the force or trauma experienced to a specific anatomical region during RTA.[33–35] Complex fractures, which encompass irregular (33.3%) and comminuted segmental (22.3%) fractures, are more commonly observed in high-impact incidents, whereas wedge fractures tend to occur in scenarios characterized by moderate impact.[36] Significantly, our observation underscores that high-impact RTA injuries are more frequently encountered in low to middle-income economies, primarily due to the widespread use of two-wheelers. This highlights a stark disparity in the types of fractures associated with ligamentous knee injuries between low to middle-income economies and their middle to high-income counterparts worldwide.

Moreover, our study also revealed that MCL (44.4%) was the most common type of ligamentous knee injury accompanying a femur shaft fracture, closely followed by ACL (33.3%) and LCL (22.2%). This finding is consistent with the findings of Walker et al.,[13] who presented that ACL was the commonest (50%) and MCL was the second most common (31%) ligamentous knee injury in femoral shaft fractures. However, it is noteworthy that our statistics slightly differ from those of Walker et al.,[13] as our study identified MCL as the most common ligamentous knee injury. This variation can be elucidated by a study conducted by Nagaraj et al.,[33] that found that ACL (36.7%) and MCL (41.7%) injuries were prevalent in cases involving RTA, which are often high-impact in terms of force that result in hyperextension of the knee joint, thereby subjecting the ACL and MCL ligaments to excessive stress, leading to ligamentous knee injuries. These findings were lacking in prior studies, as none studied the most common type of knee injury occurring in femoral shaft fracture, where RTA is the most significant risk factor.

Furthermore, our study also presented a positive and significant association of ACL and MCL types of ligamentous knee injury accompanying femoral shaft fracture with 18–25 years of age, RTA as a mechanism of injury, and a complex and close type of fracture, which was lacking in previous decades of studies on this topic[4–9,12] and resulted in a novel finding. The association of type of knee injury with age is because RTA is the most significant risk factor for a ligamentous knee injury in low-middle-income countries encompassing younger age groups due to densely populated areas and using two-wheelers as a primary source of transportation. Injuries from these generally result in a complex and close type of fracture of the femoral shaft, which is now known to be associated with ligamentous knee injuries. The above-mentioned findings suggest the risk factors for ACL and MCL are the two most typical types of ligamentous knee injuries accompanying femoral shaft fractures in a low-middle-income economy.

The following are some limitations of this study: First, because this study was limited to two tertiary care institutions in Karachi while omitting other hospitals, statistics from other hospitals may differ slightly. Second, the clinical assessment and treatment were performed by multiple skilled surgeons, so clinical expertise may differ from surgeon to surgeon, potentially resulting in some bias. Third, this study utilized the consecutive sampling technique, which might be considered weak if not done correctly. Another limitation of this study is not being able to utilize MRI for the definitive diagnosis of ligamentous knee injury in all patients due to the utilization of stainless steel so the incidence reported might still be slightly lower or mis/underdiagnosed, due to not being able to utilize MRI in stainless steel implant patients. Moreover, the mitigation of potential occurrences of false negatives and false positives was addressed through the rigorous adherence to standardized clinical test protocols, thereby ensuring uniform application across the entirety of the participant cohort. Furthermore, the validation of outcomes was facilitated through cross-validation among multiple surgeons, supplemented by MRI scans. Nonetheless, it is important to acknowledge that despite these measures, a marginal possibility of false positives or negatives persists. Last limitation is not being able to use binary logistic regression to show association due to a number of reasons: Sample size not large enough to show the association with logistic regression, Dependency, Inclination of all the response towards one variable, Multicollinearity, and Overfitting. This study has several strengths, including the fact that it is being conducted in a low-middle-income country for the first time, as well as two of Karachi's busiest orthopedic setups for trauma, where patients are brought as a first choice, and the income of patients does not matter because treatment is primarily free or low-cost. One of the study's limitation is the use of the consecutive sampling technique, which is its strength as it allows looking up a relatively more significant number of samples in a short period through a multi-center study, as compared to prior studies that were single-center and had a small sample size. Another strength of this study lies in it being prospectively conducted with a variety of patients with ligamentous knee injury giving generalized results, and providing real-time data compared to previous studies that were conducted retrospectively.

Conclusion

Our findings brought to light the concerning and unresolved fact that ligamentous knee injuries associated with femoral shaft fractures are highly prevalent in a low-middle-income economy, that is, Karachi-Pakistan. The MCL and ACL were identified as the most common ligamentous knee injuries accompanying a femoral shaft fracture due to an RTA, which is now evident to be a risk factor in a low-middle-income economy. Emergency Room (ER) clinicians and orthopedic surgeons can use this study to gain a general understanding of what to expect in patients with femoral shaft fractures and treat them accordingly. This study also established a baseline for middle-to-high-income economies to identify risk factors in order to provide proper and timely diagnosis and treatment in patients with ligamentous knee injuries linked with femoral shaft fractures. Additional research, encompassing retrospective and prospective studies spanning multiple years, is warranted to comprehensively elucidate the degree of association between ligamentous knee injuries and various risk factors.

Author's note

Muhammad Hamza Dawood and Muhammad Gulfam Shahzad are the first authors of this study.

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Authors contributions

MGS and MHD are the guarantors of the study. MHD was involved in Instrument development, majority manuscript writing/Critically revising, Data Coding, Interpretation and Data Analysis. MGS is the principal investigator of this study and was involved in Research Proposal, Study design, manuscript writing, data collection as well as supervision. HP, MD, SS, and MR were involved in Data Collection, Data entry, critically revising and proof-reading. All authors have authorized the final manuscript version.

Data availability statement

The deidentified datasets that support the findings of this study are available from the corresponding author on reasonable request.

Declaration of conflicting interests

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Ethical approval

This study was approved by the Institutional review board of Shaheed Mohtarma Benazir Bhutto Institute of Trauma at Karachi city (Ref.#: ERC-000035/SMBBIT/Approval/2021). The identical ethical endorsement stands valid and is uniformly acknowledged within both participating institutions, owing to the affiliative relationship of the second hospital as a sister institute.

Informed consent

Written Informed and Verbal Consent was taken from all the patients for their participation during the collection process.

Trial registration

Not applicable.

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Supplemental material

Supplemental material for this article is available online.

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