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Comprehensive Evaluation of Magnetic Resonance Imaging-Detected Knee Ligamentous Injuries and Their Correlation with Outerbridge Classification of Articular Cartilage Degeneration

Ali Noman*[1], Jawaria Munawar[2], Ajwa Chaudhry[3], Alishba Choudry[4], Dilshad Zahoor[5], Muhammad Arshad[6], Alishba Tahir[7]

[1]*Supervisor, BS MIT, MS AHS (MIT), Faculty of Allied Health Sciences, Pakistan*
[2,3,4,5,6]*Student, Bachelor of Medical Imaging Technology, Pakistan*
[7]*Pakistan Avicenna Medical College & Allied Health Sciences*

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Knee ligament injury, MRI, Outerbridge classification, cartilage degeneration, ACL, PCL, MCL, LCL.

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Corresponding Author: *
Mr. Ali Noman
ali.noman@superior.edu.pk

Abstract
Background:
When assessing knee ligament injuries, magnetic resonance imaging is frequently utilized to determine the extent of damage and associated cartilage degeneration. The Outerbridge rating system is one widely used grading scheme for evaluating cartilage degradation. Therapy and patient outcomes can be enhanced by knowing how knee ligament injuries link to the Outerbridge system.
Objective: *To Correlation of knee ligament injury on magnetic resonance imaging with outer bridge system.*
Methodology:*53 patients in this study had MRI-confirmed knee ligament injuries. The anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), medial collateral ligament (MCL), and lateral collateral ligament (LCL) were all visibly damaged. Those with cartilage degeneration were categorized into grades 0 through IV using the Outerbridge technique. By examining the data, the relationship between ligament injuries and the extent of cartilage damage was assessed.*
Results: *Out Of the 53 patients, 41 had an ACL injury, which made up 77.35% of the total. PCL injuries came in at 19, MCL injuries at 1, and LCL injuries at 1. There were no patients with Grade IV cartilage degeneration, according to the Outerbridge categorization results; 15 patients had Grade 0, 20 had Grade I, 17 had Grade II, and 8 had Grade III. Road traffic accidents (RTAs) were the principal cause in 27 cases (50.94%). Higher Outerbridge grades were strongly correlated with the severity of ligament damage, especially in chronic instances.*
Conclusion: *An effective method for evaluating knee ligament damage and related cartilage degradation is magnetic resonance imaging. The degree of cartilage degeneration, as assessed by the Outerbridge method, was found to be correlated with ligamentous injury. Early identification of cartilage alterations and ligament damage by MRI may provide prompt intervention and enhance knee injury care.*

INTRODUCTION
Injuries to the knee ligaments are among the most common musculoskeletal injuries, particularly in individuals participating in sports and athletic activities. These injuries frequently occur in sports that involve rapid acceleration, deceleration, pivoting, jumping, and direct physical contact. Ligament ruptures disturb the balance between knee stability and mobility, resulting in pain, instability, reduced functional

capacity, and increased morbidity. They can lead to abnormal knee kinematics and cause secondary damage to intra-articular and periarticular tissues, including the menisci, cartilage, capsule, and subchondral bone. Multi-ligament knee injuries (MLKIs) are complex knee injuries that involve damage to two or more major stabilizing ligaments. The intricacy of these injuries and their potential for adverse outcomes may make treatment difficult and challenging (1).

The Anterior Cruciate Ligament (ACL), Posterior Cruciate Ligament (PCL), Medial Collateral Ligament (MCL) along with the posteromedial corner, and Lateral Collateral Ligament (LCL) along with the posterolateral corner are the four primary knee ligaments involved in MLKIs. An anterior cruciate ligament tear is a common and devastating sports injury that frequently occurs in adolescents and young adults (2). The ACL is one of the two cruciate ligaments that maintain knee joint stability. The most common sports associated with knee ligament injuries include football, basketball, and soccer (3). These sports involve pivoting, cutting, and high-impact activities that place excessive stress on the knee joint.

The anterior cruciate ligament is essential for coordinated lower extremity movement because it controls knee motion in six degrees of freedom: three translations and three rotations. It prevents excessive anterior translation of the tibia relative to the femur and guides the ―screw-home‖ mechanism during terminal knee extension. Additionally, the ACL plays a crucial role in knee proprioception. Proprioception within the somatosensory system is essential for optimal human function. Its main purpose is to provide afferent sensory information regarding joint position and movement, contributing to neuromuscular control and dynamic stability (4).

A common mechanism of ACL injury is Valgus and External Rotation (VRE), in which the knee collapses inward while externally rotating. Another mechanism involves Varus and Internal Rotation (VRI), where the knee experiences outward force with internal rotation stress. These biomechanical patterns disrupt ligament integrity and compromise joint stability. The Posterior Cruciate Ligament (PCL) is one of the primary ligaments supporting the knee joint and is essential for maintaining posterior stability. Compared to ACL injuries, isolated PCL ruptures may significantly impair knee function before surgical intervention (5).

Fig 1: Partial ACL Tear

A fat-suppressed proton-density sagittal view of an acute partial ACL tear depicts focal increased signal of the ACL (arrowheads) and a wavy contour of posterior fibers, which remain in continuity (arrow).

The Medial Collateral Ligament (MCL) is one of the four major ligaments that stabilize the knee. It serves as the primary static stabilizer of the medial compartment and resists valgus stress, rotational forces, and anterior translational loads. The MCL is the most commonly injured ligament of the knee. Athletes who participate in sports that require sudden directional changes or involve contact are at increased risk of sustaining acute MCL injuries due to valgus stress (6). MCL injuries frequently occur in combination with ACL tears, contributing to joint instability and functional impairment.

The Lateral Collateral Ligament (LCL) functions as the primary stabilizer against varus stress at all degrees of knee flexion. It also resists excessive external rotation near full extension. LCL injuries are often associated with posterolateral corner (PLC) injuries rather than occurring in isolation. Common associated injuries include avulsion of the lateral capsular structures, iliotibial band injuries, biceps femoris tendon damage, fibular head fractures, and injury to the common peroneal nerve at the PLC (7). These combined injuries can significantly compromise knee stability and complicate management.

Several variables are associated with the prevalence of knee ligament injuries. These include sports discipline, improper equipment use, environmental conditions, training errors, level of competition, growth and developmental factors, previous injuries, sex differences, and psychological factors (8). Female athletes have been reported to have a higher incidence of ACL injuries due to anatomical, hormonal, and neuromuscular factors.

Obesity is strongly associated with degeneration of the osteo-articular system and accelerates wear and tear of cartilage and other articular structures. Osteoarthritis (OA) is the most prevalent form of arthritis and affects millions of adults worldwide. Approximately 90 million adults in the United States alone are affected, representing a significant proportion of the adult population (9). The knee joint is one of the most commonly affected weight-bearing joints. OA primarily involves degeneration of the articular hyaline cartilage but also affects the subchondral bone and synovial membrane, contributing to disease progression (10).

Progression of osteoarthritis is characterized by osteophyte formation, cartilage deterioration, joint space narrowing, subchondral bone sclerosis, inflammation, pain, and edema (11). Several risk factors contribute to OA development, including advanced age, female gender, obesity, congenital joint abnormalities, and acute joint trauma. Systematic reviews suggest that aging and increased body mass index (BMI) exacerbate degenerative changes within the knee joint (12). Recurrent ligament injuries may further accelerate cartilage degeneration and predispose patients to early osteoarthritis (13).

Completely preventing knee ligament injuries remains challenging. The goal of multidisciplinary medical teams is to reduce injury risk through proper diagnosis, structured rehabilitation, load management, and training modifications (14). Selecting appropriate training intensity and recovery strategies is essential in minimizing overuse injuries. Adequate knowledge among trainers and healthcare professionals assists in planning suitable conditioning programs, thereby reducing injury risk, particularly those related to overtraining (15).

The Outerbridge classification system was developed to provide a simple, reproducible, and user-friendly method for grading articular cartilage lesions. It categorizes cartilage damage from Grade 0 to Grade IV (16). Grade I lesions involve cartilage softening and swelling. Grade II lesions are partial-thickness defects with fissures that do not extend to

the subchondral bone. Grade III lesions involve fissuring that reaches the subchondral bone without complete exposure. Grade IV represents full-thickness cartilage loss with exposed subchondral bone (17). This classification system is widely used in clinical practice and research to standardize cartilage 8assessment (18).

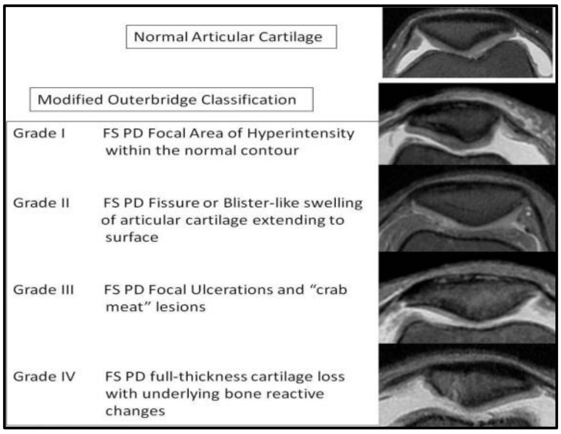

Fig 1: Modified Outerbridge Classification.

Early detection of injured structures is essential for effective management of MLKIs. Magnetic Resonance Imaging (MRI) is a crucial non-invasive imaging modality for evaluating knee ligament injuries (19). MRI is highly sensitive in detecting cruciate and collateral ligament tears. However, its diagnostic accuracy in multi-ligament injuries and associated meniscal or posterolateral corner injuries may vary (20). Despite these limitations, MRI remains indispensable for comprehensive preoperative evaluation (21).

MRI is also a validated imaging technique for assessing articular cartilage of the knee joint. It enables detection and monitoring of degenerative changes that may progress to osteoarthritis (22). MRI provides detailed visualization of cartilage morphology and pathology. With reported diagnostic accuracy of up to 91%, MRI is considered a highly reliable non-invasive method for cartilage assessment in conjunction with established grading systems (23).

The Outerbridge classification system remains an established and widely accepted method for categorizing cartilage damage. Its application in this study enables accurate correlation between MRI-detected knee ligament injuries and the severity of cartilage lesions (24). By systematically grading cartilage damage and comparing it with ligamentous pathology identified on MRI, this study enhances diagnostic precision and supports improved clinical decision-making. Ultimately, such correlation contributes to better patient outcomes, more targeted treatment strategies, and optimized therapeutic approaches for knee joint injuries (25).

OBJECTIVES

To Correlation of knee ligament injury on magnetic resonance imaging with outer bridge system

METHODOLOGY

This study used a descriptive cross-sectional design and was conducted at Aznostic Diagnostic Centre Lahore, IDC, and Mayo Hospital Lahore. The duration of the study was four months after approval of the synopsis. A sample size of 53 patients was calculated using the standard formula.

Participants were selected through a non-convenient sampling technique. Inclusion criteria included patients with sports injuries and confirmed ligament injuries. Exclusion criteria were previous knee surgery, concurrent lower limb injuries, and chronic knee conditions. RI of the knee was performed using 1.5T or 3T scanners with a dedicated knee coil. Patients were positioned supine with slight knee flexion for accurate imaging. Images were obtained in axial, sagittal, and coronal planes using standard sequences. Ligaments (ACL, PCL, MCL, LCL) were assessed for partial or complete tears. Articular cartilage was graded using the Outerbridge classification, and associated findings were recorded. Data were analysed on PACS using Chi-square and correlation tests, with $p < 0.05$ considered significant.

RESULTS

The study involved a total of 53 individuals to evaluate the correlation between knee ligament injuries observed on magnetic resonance imaging (MRI) and cartilage damage classified by the Outer Bridge system. The sample population showed a marked male predominance, with 39 males (73.6%) and 14 females (26.4%). In terms of age distribution, the largest group was aged 30–45 years (50.9%), followed closely by individuals aged 15–30 years (47.2%). Only one participant (1.9%) was in the 45–60 age group. The most common cause of injury was road traffic accidents (RTAs), accounting for 50.9% of cases, followed by pain-related complaints without specific trauma (37.7%), and sports injuries (11.3%). MRI analysis revealed a high prevalence of anterior cruciate ligament (ACL) injuries, present in 77.4% of individuals. Posterior cruciate ligament (PCL) injuries were observed in 35.8% of cases, indicating they are less common than ACL injuries. Injuries to the medial collateral ligament (MCL) and lateral collateral ligament (LCL) were extremely rare, each reported in only 1.9% of the cases. Evaluation using the Outer Bridge classification showed a predominance of absent findings across all grades, suggesting limited cartilage degeneration in most patients. Specifically, general Outer Bridge findings were absent in 73.6% of cases and present in 26.4%. Grade I lesions were present in 30.2% and absent in 69.8% of cases. Grade II lesions were noted in 32.1%, while 67.9% were absent. Grade III lesions were observed in only 11.3% of the population, with an 88.7% absence rate. The most severe cartilage damage, classified as grade IV, was present in just 1.9% of cases and absent in 98.1%.

These findings suggest a strong association between ACL injuries and early-stage cartilage changes, while severe chondral damage remains uncommon in the studied population. The data highlights the value of MRI in detecting soft tissue and cartilage abnormalities and suggests that early intervention could prevent progression to advanced degenerative joint disease.

Table 4.1
Table of Gender Distribution

TABLE 1 presents a breakdown of a sample population by gender. Out of a total of 53 individuals, 39 are male, accounting for 73.6% of the sample, while 14 are female, representing 26.4%. This indicates a significant male majority in the population surveyed.

Gender		
Male	39	73.6
Female	14	26.4
Total	53	100.0

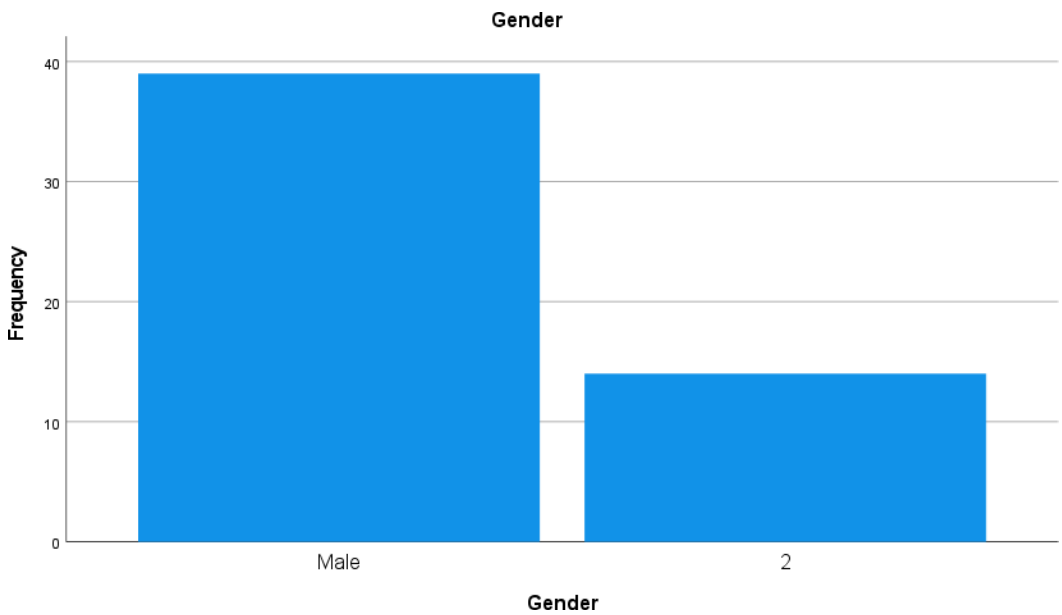

Figure- 4.1; Graph representing the gender groups of patients

Table 4.2
Frequency Table of Splenomegaly
The age distribution of the sample population consists of three groups. The largest group is aged 30-45, with 27 individuals, making up 50.9% of the total, followed closely by the 15-30 age group, which includes 25 individuals or 47.2%. The 45-60 age group is significantly smaller, with only 1 individual, representing 1.9% of the total population.

Age		
	Frequency	Percent
Age group 15-30	25	47.2
Age group 30-45	27	50.9
Age group 45-60	1	1.9
Total	53	100.0

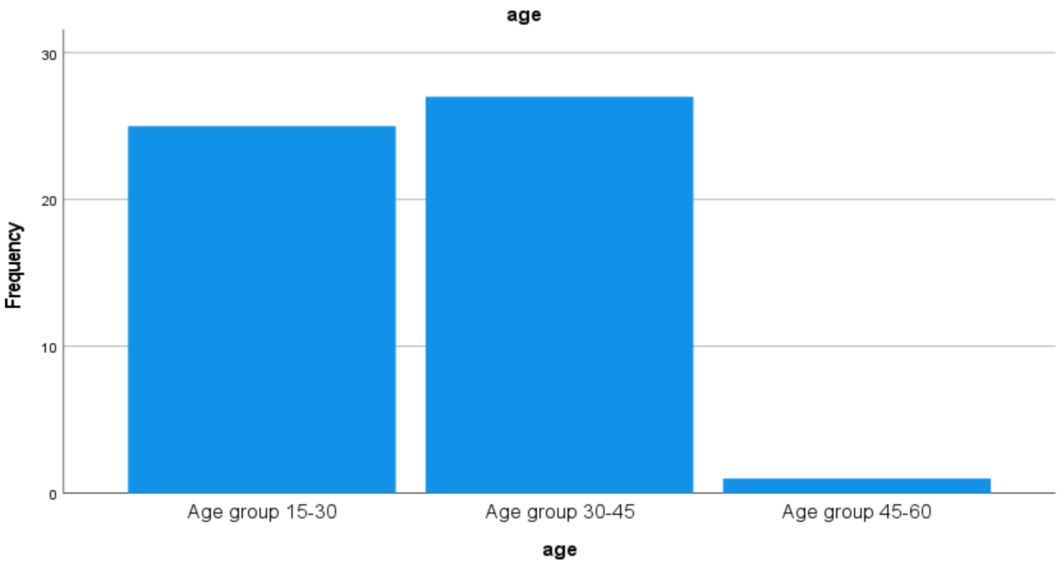

Figure- 4.2; Graph representing the age groups of patients

Table- 4.3;
Frequency Distribution of Causes of Injuries.
The data categorizes the causes of injuries within a sample population of 53 individuals. The most common cause is road traffic accidents (RTA), accounting for 27 cases or 50.9% of the total. Pain is the second most frequent cause, with 20 cases (37.7%), while sports injuries are the least common, comprising only 6 cases (11.3%).

	Frequency	**Percent%**
Pain	20	37.7
Sports injury	6	11.3
RTA	27	50.94
Total	53	100.0

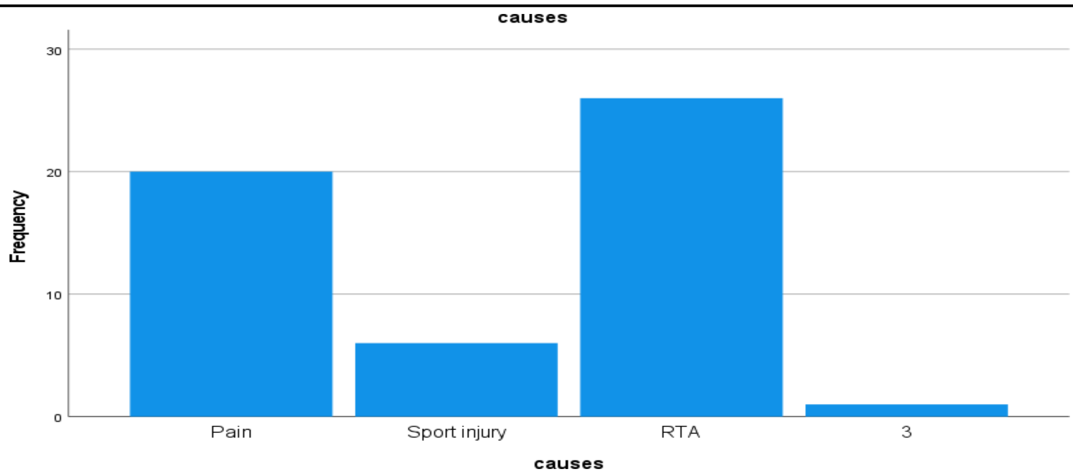

Figure- 4.3; Graph representing the causes of injury among patients

Table- 4.4;
Frequency Distribution of ACL injuries among patients.
TABLE presents the status of anterior cruciate ligament (ACL) injuries among a sample of 53 individuals. A majority of the participants, 41 individuals or 77.4%, have a present ACL injury, while 12 individuals, representing 22.6%, show an absent ACL injury. This indicates a high prevalence of ACL injuries within the surveyed population.

Ligaments Injury ACL		
	Frequency	Percent
Absent	12	22.6
Present	41	77.4
Total	53	100.0

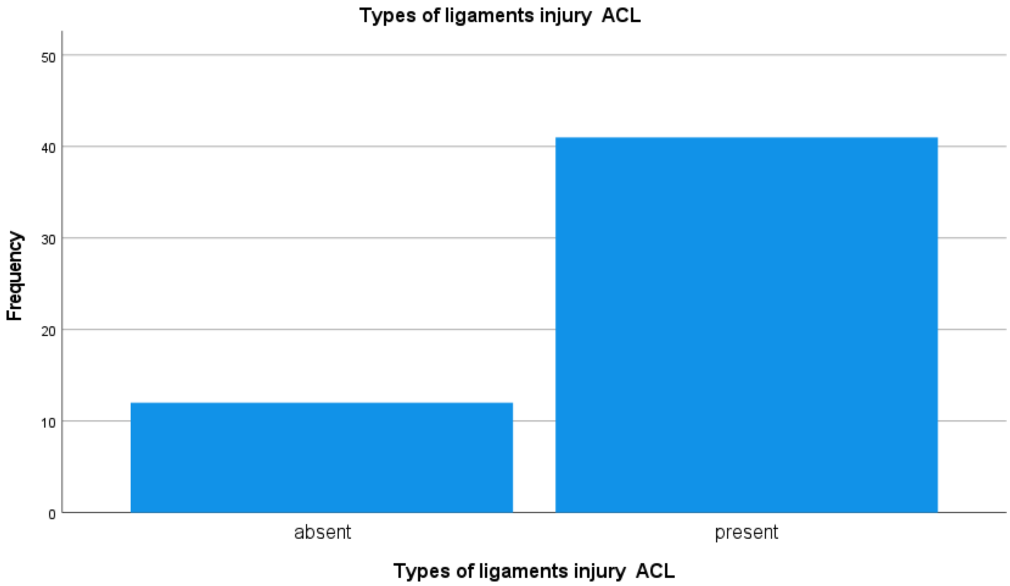

Figure- 4.4; Graph representing the frequency of type of ACL injury

Table- 4.5;
Frequency Distribution of PCL injuries among patients.
The data outlines the status of posterior cruciate ligament (PCL) injuries in a sample of 53 individuals. A significant majority, 34 individuals or 64.2%, have an absent PCL injury, while 19 individuals, representing

35.8%, have a present PCL injury. This suggests that PCL injuries are less common in this population compared to those with absent injuries.

Ligaments injury of PCL		
	Frequency	Percent
Absent	34	64.2
Presnt	19	35.8
Total	53	100.0

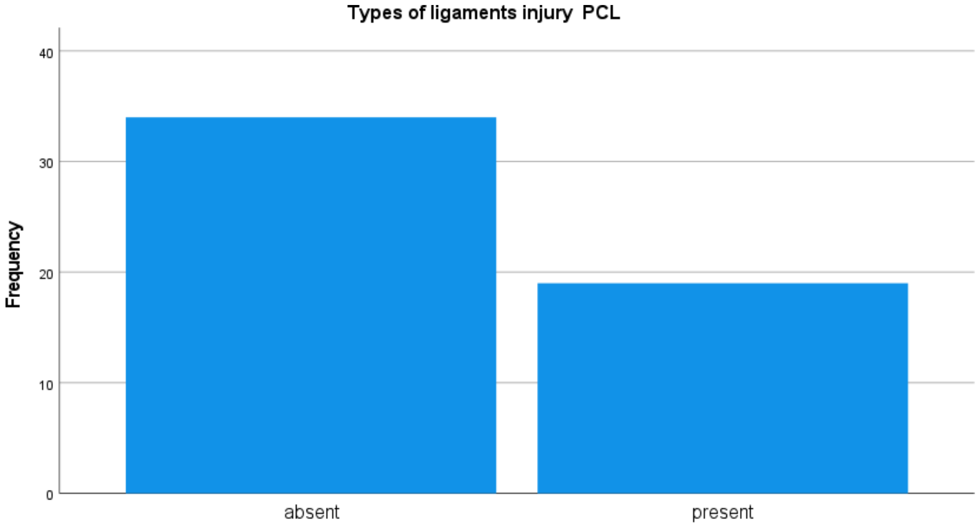

Figure- 4.5; Graph representing the frequency of type of PCL injury

Table- 4.6;
Frequency Distribution of MCL injuries among patients.

The data details the status of medial collateral ligament (MCL) injuries among a sample of 53 individuals. An overwhelming majority, 52 individuals or 98.1%, have an absent MCL injury, while only 1 individual, representing 1.9%, has a present MCL injury. This indicates that MCL injuries are extremely rare in this population.

Ligaments injury of MCL		
	Frequency	Percent
Absent	52	98.1
Present	1	1.9
Total	53	100.0

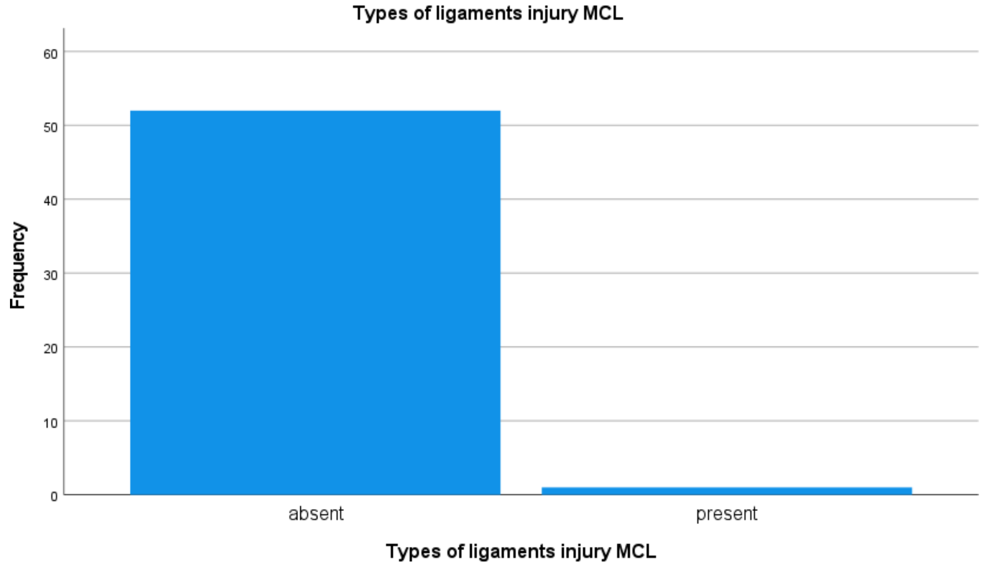

Figure- 4.6; Graph representing the frequency of type of MCL injury

Table- 4.7;
Frequency Distribution of LCL injuries among patients.

The data presents the status of lateral collateral ligament (LCL) injuries in a sample of 53 individuals. Similar to the findings for the medial collateral ligament, 52 individuals, or 98.1%, have an absent LCL injury, while only 1 individual, representing 1.9%, has a present LCL injury. This indicates that LCL injuries are also very rare within this population.

Ligaments injury of LCL		
	Frequency	Percent
Absent	52	98.1
Present	1	1.9
Total	53	100.0

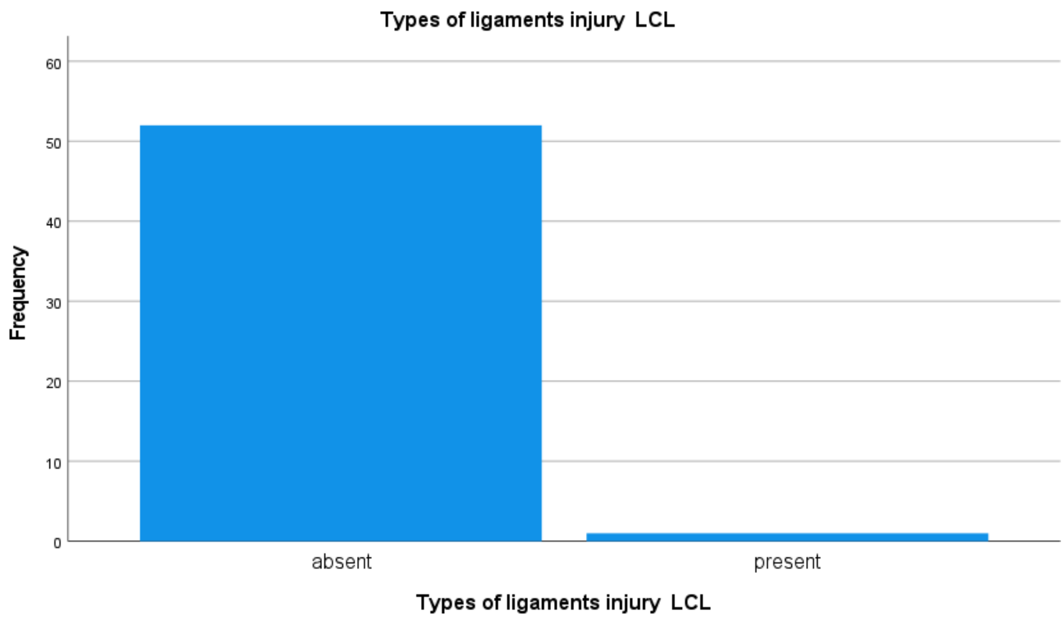

Figure- 4.7; Graph representing the frequency of type of LCL injury

Table- 4.8;
Frequency Distribution of Data on the outer bridge system 0 among patients

The table presents data on the outer bridge system, indicating that 39 cases (73.6%) are classified as absent, while 14 cases (26.4%) are classified as present. In total, there are 53 cases analyzed. This distribution highlights a predominance of absence in the outer bridge system among the observed cases.

Outer Bridge System 0		
	Frequency	Percent
Absent	39	73.6
Present	14	26.4
Total	53	100.0

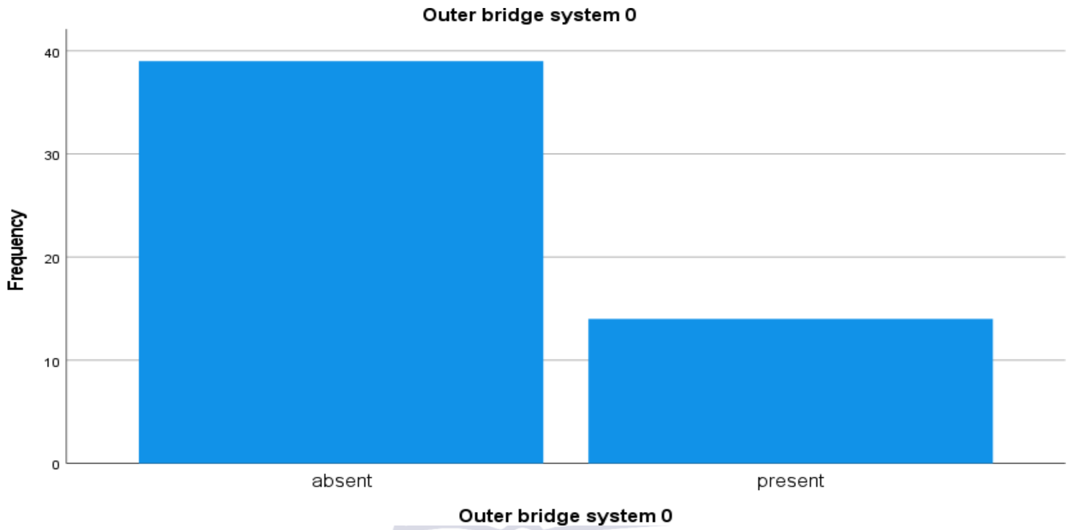

Figure- 4.8; Graph representing the frequency of Outerbridge sytem 0 among the patients

Table- 4.9;
Frequency Distribution of Data on the outer bridge system 1 among patients.

The table displays the results for the outer bridge system 1, revealing that 37 cases (69.8%) are classified as absent, while 16 cases (30.2%) are classified as present. This indicates a majority of the cases do not exhibit the outer bridge system. The total number of cases analyzed is 53, reflecting a notable presence of absence in this assessment.

Outer Bridge System 1		
	Frequency	Percent
Absent	37	69.8
Present	16	30.2
Total	53	100.0

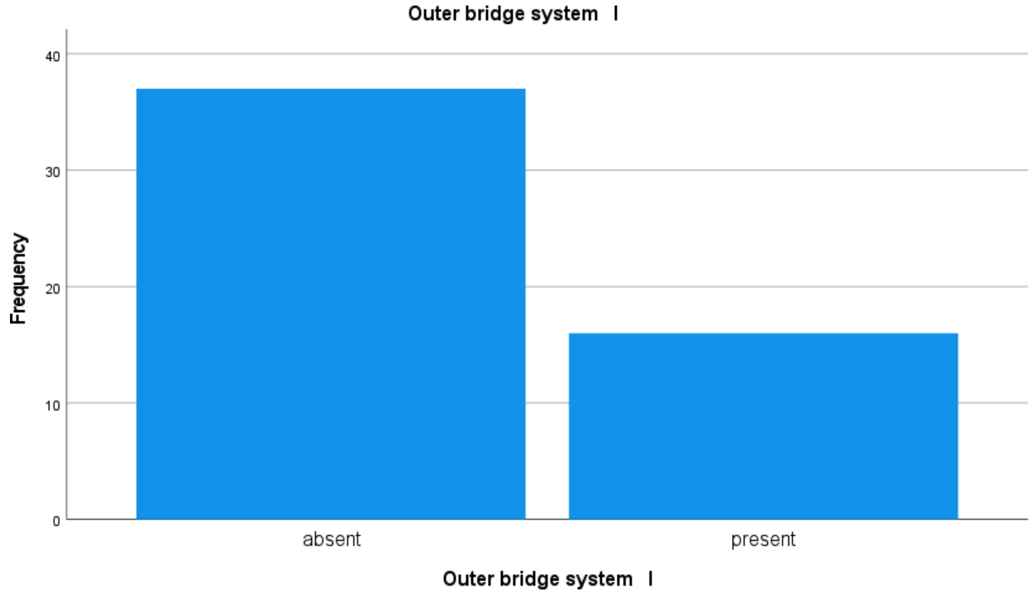

Figure- 4.9; Graph representing the frequency of Outerbridge system 1 among the patients

Table- 4.10;
Frequency Distribution of Data on the outer bridge system 2 among patients.

The table outlines the results for the outer bridge system II, indicating that 36 cases (67.9%) are classified as absent, while 17 cases (32.1%) are classified as present. This shows a continued trend of higher absence rates compared to presence. The total number of cases analyzed remains at 53, suggesting a consistent pattern across the assessments of the outer bridge systems.

Outer bridge system II		
	Frequency	Percent
Absent	36	67.9
Present	17	32.1
Total	53	100.0

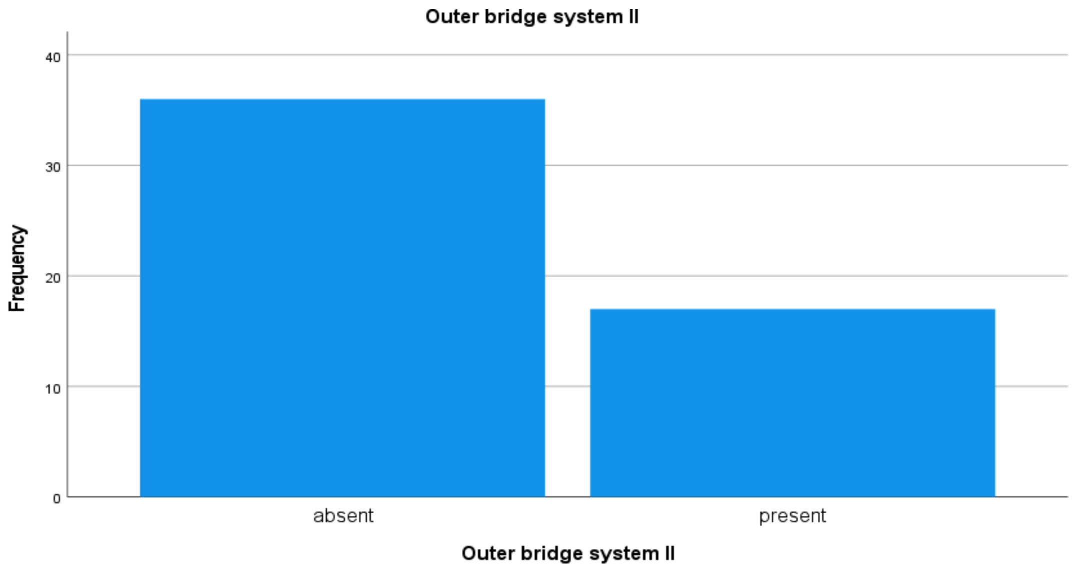

Figure- 4.10; Graph representing the frequency of Outerbridge system 2 among the patients

Table- 4.11;
Frequency Distribution of Data on the outer bridge system 3 among patients.

The table presents the findings for the outer bridge system III, showing that 47 cases (88.7%) are classified as absent, while only 6 cases (11.3%) are classified as present. This indicates a significant predominance of absence in this assessment compared to previous outer bridge systems. With a total of 53 cases analyzed, the data highlights a marked decline in the presence of the outer bridge system I

Outer bridge system III		
	Frequency	Percent
Absent	47	88.7
Present	6	11.3
Total	53	100.0

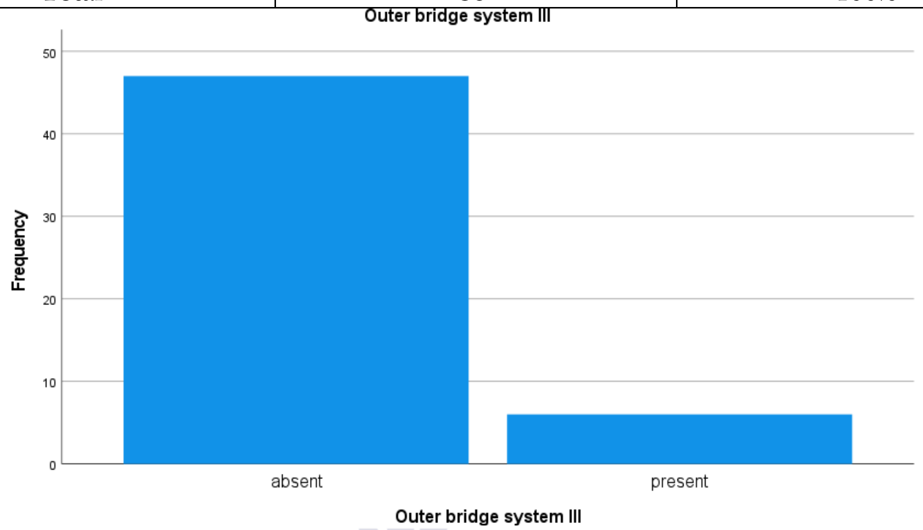

Figure- 4.11; Graph representing the frequency of Outerbridge system 3 among the patients

Table- 4.12;
Frequency Distribution of Data on the outer bridge system 4 among patients.

The table results for the outer bridge system IV, revealing that 52 cases (98.1%) are classified as absent, while only 1 case (1.9%) is classified as present. This indicates an overwhelming majority of absence in this assessment, representing the highest absence rate among the outer bridge systems analyzed. With a total of 53 cases, the data underscores a stark contrast in the presence of the outer bridge system IV.

outer bridge system IV		
	Frequency	Percent
Absent	52	98.1
Present	1	1.9
Total	53	100.0

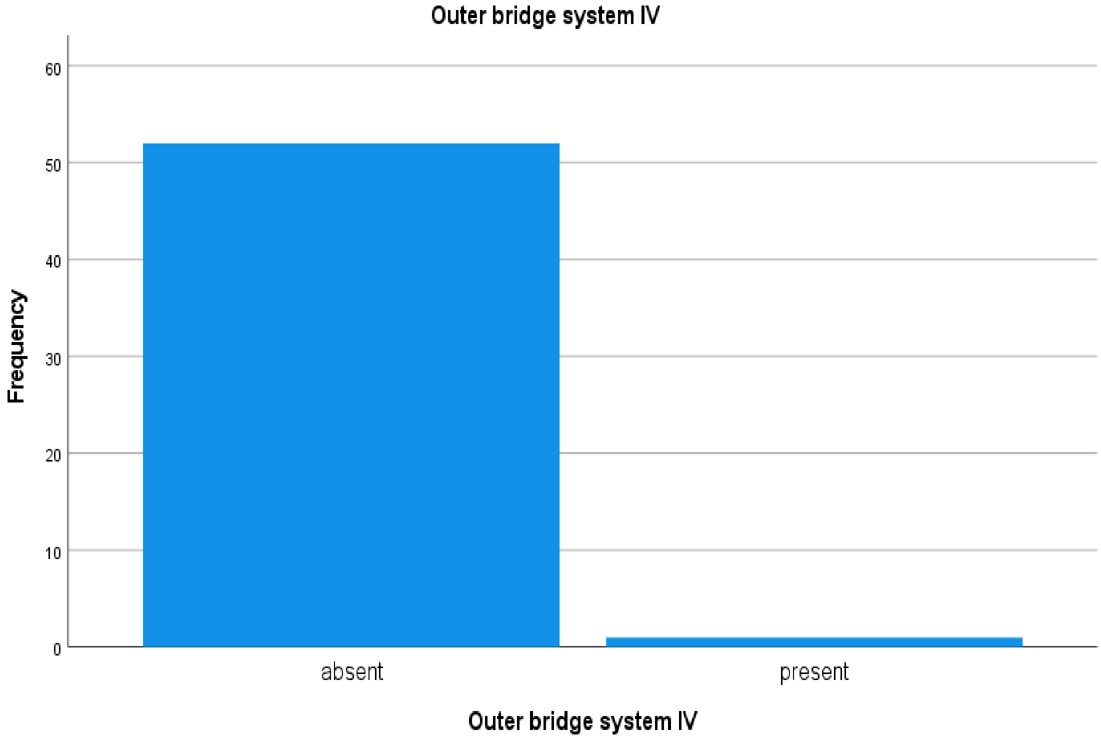

Figure- 4.12; Graph representing the frequency of Outerbridge system 4 among the patients

Table- 4.13;
Correlation of Outer Bridge Grading system with the types of knee injuries.

Outer bridge system (Grading)	Types of Knee injuries			
	ACL (41n)	PCL (19n)	MCL (1n)	LCL (1n)
O (15n)	13	2	0	0
I (20n)	8	10	1	1
II (17n)	14	5	0	0
III (8n)	6	2	0	0
IV(0n)	0	0	0	0

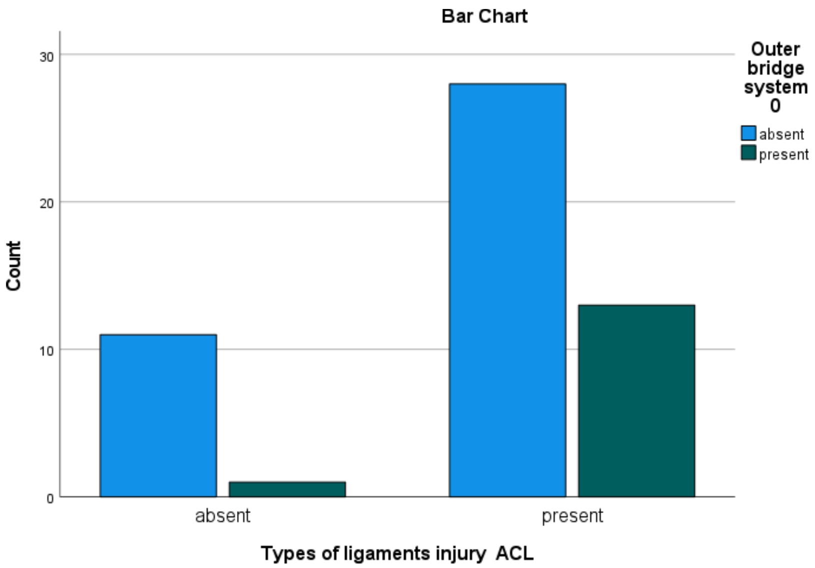

Figure- 4.13; Graph representing the correlation of Outerbridge system and type of injury among the patients

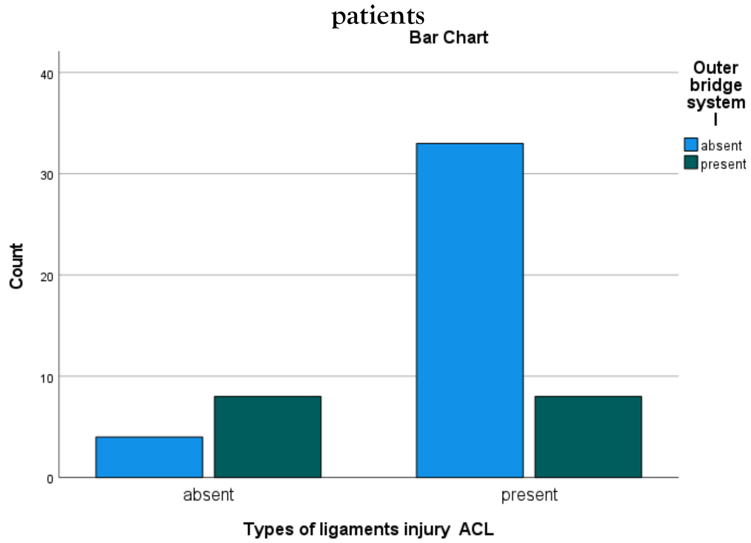

Figure- 4.10; Graph representing the correlation of Outerbridge system and type of injury among the patients

We take 53 patients of knee MRI showing evidence of knee ligaments injuries at MRI. In which anterior cruciate ligaments is 41(77.35%) patients with outer bridge system (grading 0) 13 (31.7%) patients, grading i 8(19.7%) patients, grading ii 14 (34.4%) patients, grading iii 6(14.5%) patients and grading iv having 0 (0%) patients. Posterior cruciate ligaments are 19(35.8%) patients with outer bridge system (grading 0) 2 (10.5%) patients, grading i 10(52.7%) patients, grading ii 5 (26.4%) patients, grading iii 2(10.5%) patients and grading iv having 0 (0%) patients. Medial cruciate ligaments patients are 1 (1.88%) patient with grading 1. Lateral cruciate ligaments patients are 1 (1.88%) patient with grading 1. The main clinical presentation was knee pain, sports injuries and RTA. The patient presenting with knee pain are 20(37.7%). The patients presenting with knee sports injuries are 6(11.32%). The patients presenting with knee RTA are 27(50.94%). This study group consisted of 14 female and 39 male patients.

DISCUSSION

Magnetic resonance imaging is frequently used to diagnose knee ligament injuries in order to determine the amount of the damage and spot any related abnormalities in the cartilage. Based on MRI results, the Outerbridge categorization system is frequently used to classify cartilage degeneration. One can gain a better understanding of how ligamentous damage affects cartilage health by comparing knee ligament injuries with the Outerbridge system. Improved diagnosis, treatment planning, and prognosis for individuals with knee injuries can result from an understanding of this relationship. The prevalence of ankle ligament injuries, especially anterior cruciate ligament rupture, is higher in athletes and is around 68.6 per 100,000 person-years worldwide. Particularly in patients with persistent or post-traumatic arthritis, the Outerbridge system's description of cartilage deterioration and ligament damage can occasionally happen simultaneously.

Zhan X et al in 2022 conducted a study investigates how well acute traumatic multiple ligament knee injuries (MLKIs) may be identified and categorized using magnetic resonance imaging (MRI). Using sensitivity, specificity, predictive values, likelihood ratios, and kappa coefficient analysis, Intraoperative observations and MRI categorization accuracy for MLKIs were contrasted (40). 53 study participants were evaluated after knee MRIs showed ligament damage. ACL injuries were present in 41 individuals (77.35%), PCL injuries in 19, MCL injuries in 1, and LCL injuries in 1. Furthermore, 27 patients (50.94%) suffered knee injuries in road traffic accidents (RTAs) (36).

Sieron et al. In 2022 investigated the association between age, gender, and chondropathy in the femorotibial joint using the Outerbridge categorization system. Using 1.5T and 3.0T MRI scanners, they discovered a significant correlation between patient age and Outerbridge grade in all femorotibial joint compartments (The following categories were used to group the patients in our study: Twenty patients received an I, seventeen received an II, eight received a III, fifteen received a zero, and none of the patients received an IV. There were 39 male patients and 14 female patients in our study group (37)

Li X and Hou et al in 2012 examined the ability of MRI to detect specific ligament damage in MLKIs with both sensitivity and specificity. For detecting ACL (90.7%) and PCL (90.4%) injuries, they found good sensitivity but low specificity (PCL: 50%, ACL: 63.6%). MCL detection exhibited an intermediate sensitivity (79.1%) and specificity (46.7%), while LCL identification had a higher specificity (68.4%) but a lower sensitivity (55.6%). This study looked at 53 patients who had knee ligament injuries confirmed by MRI. This comprises 19 patients with PCL, 1 with MCL, 1 with LCL, and 41 patients (77.35%) with anterior cruciate ligaments. Furthermore, 27 patients (50.94%) were injured as a result of RTAs (38).

Von Rehingen et al in 2022 conducted MRI scans were performed on 30 patients with MCL injuries (53% female, mean age 37 ± 13 years, range 16–68 years). 60% of all injuries were Type I, with Type III (33.3%), Type II (3.3%), and Type Ib (3.3%) coming in close second and third, respectively. There were no reports of Type III injuries (39). One patient with Outerbridge Grade I MCL damage was included in our study

CONCLUSION

This study demonstrates a correlation between knee ligament injuries identified on MRI and cartilage degeneration graded by the Outerbridge system. The findings suggest that ACL injuries are the most common, with a higher likelihood of cartilage damage as the severity of ligamentous injury increases. MRI serves as a valuable tool for evaluating both ligament injuries and associated cartilage degeneration, aiding in accurate diagnosis and treatment planning. Early detection and timely intervention may help prevent the progression of cartilage damage and improve long-term joint function

Limitation

The study was limited to 53 patients, which may not fully represent the broader population. A larger cohort is needed for more generalized conclusions. The study did not assess long-term outcomes of cartilage degeneration, which could provide insights into disease progression. The data were collected from a single medical center, which may introduce selection bias and limit the generalizability of the findings. MRI findings were not compared with arthroscopic or histopathological results, which could have provided more accurate validation of cartilage degeneration severity. Differences in MRI machine specifications and operator expertise may affect the consistency of imaging interpretation.

Recommendations

1. Future research should include a larger sample size across multiple institutions to enhance the validity and applicability of the findings.
2. Studies with long-term follow-ups should be conducted to assess the progression of cartilage degeneration in patients with ligament injuries.
3. Correlation with Arthroscopy

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