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Original article

Classification Based Treatment Algorithm for Patellar Sided Medial Patellofemoral Ligament Avulsion in Acute Primary Patellar Instability: A Retrospective Cohort Study

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Abstract:

Background: The purpose of this article is to re-define the medial patellofemoral ligament (MPFL) injury characteristics at its attachment to the patella and to evaluate the clinical outcomes of our treatment protocol in patients who presented acutely with first time traumatic patellar sided MPFL avulsion injuries. **Methods:** A retrospective analysis of 30 patients treated between 2020 and 2024 for acute primary lateral patellar instability with patellar-sided MPFL avulsion injuries was conducted. Patients were categorized into five types from P0 to P4 based on MRI findings and treatment protocol tailored accordingly. Kujala scores were assessed at baseline and at 3,6 and 12 months. Statistical analyses included repeated measures ANOVA and Bonferroni post-hoc testing. **Results:** The mean patient age was 18.2 years. 63.3% were female. P4 injuries were the most common (36.7%), followed by P0 (30%). Significant improvement in Kujala scores was observed across all time points (from 58.6 to 96.2 at 12 months). Both conservative and surgical groups showed parallel functional recovery, with no recurrent instability reported. **Conclusion:** Patients with P1 to P4 injuries benefitted from acute surgical repair as evidenced by the absence of recurrent instability and higher Kujala scores. This individualized approach, incorporating injury pattern and associated pathology, improves patient selection for either conservative or type of surgical management and may serve as a foundation for standardized care in acute primary patellar dislocation.

Keywords: Primary patellar instability, Medial patellofemoral ligament avulsion, MPFL augmentation, surgical technique, MPFL outcomes

Introduction

Acute patellar dislocation is the most common disorder in children and adolescents that causes functional disability [1,2]. Acute primary (first-time) patellar dislocation has been defined as a clinical entity that usually causes a traumatic disruption of the previously uninjured medical peripatellar structures and managed within four weeks after injury [3-5]. The major static medial patellar restraint that prevents lateral patellar dislocation is the medial patellofemoral ligament (MPFL) while the vastus medialis obliquus (VMO), appears to act as a dynamic stabilizer which neutralizes the lateralizing forces on the patella by vastus lateralis [6-9]. Clinical diagnosis of lateral patellar dislocation is difficult as it is usually transient. However, physical examination is important to identify and treat any concurrent knee or lower extremity injury in patients with acute patellar dislocation. It has been noted that there is a high incidence of osseous, chondral and osteochondral fractures of the medial facet of the patella and/ or the lateral femoral condyle in patients who had a more traumatic dislocation versus a patient with a lower energy mechanism, who may have one or more predisposing factors and less traumatic injury [10]. Magnetic resonance imaging (MRI) is the investigation of choice to identify specific findings that help diagnose lateral patellar dislocation [11]. Patellar side MPFL avulsion injuries were previously classified into three types as P_0, P_1 and P_2 and outcome measures of their treatment protocol were documented [12]. The aim of our study is to re-define the injury characteristics of patellar sided MPFL avulsion injuries and propose a treatment algorithm for patients with such injuries.

Materials and methods:

Between 2020 and 2024, medical records, including case sheets and electronic records, of 37 patients with a diagnosis of acute primary patellar instability, who were managed at Ortho One Orthopaedic Specialty Centre, Coimbatore, India were analyzed retrospectively. Institutional ethical committee board approval was obtained (Project No: 5/M/2025). Patients were included in the study only if there was no history of previous patellar subluxation or dislocation. The patient's age, gender, history, symptoms, radiological data, management including details of surgery and the clinical (KUJALA) scores at presentation and follow ups were retrieved. The retrieved radiological data included documented findings from kinematic CT scan of bilateral patellofemoral joints, X-rays and MRI scan of the involved knee which included the type of trochlear dysplasia if present (trochlear depth, sulcus angle), Caton-Deschamps index (patellar height), tibial tubercle-trochlear groove (TT-TG) distance. Sagittal, coronal and axial MRIs were assessed and only patellar side injuries, that were categorized based on the locations as described by Elias et al [13], were included. The documented findings from 1.5T MRI scans also included description of osseous, chondral or osteochondral fragments, its site of origin (medial patellar facet or lateral femoral condyle) and the size of such fragments.

Study Design:

A total of 67 patients were managed at our center from January 2020 to December 2024 for lateral patellar instability. Since the purpose of this study was to evaluate the clinical outcome of patients with primary acute lateral patellar dislocation having patellar sided MPFL avulsion injury, managed by our protocol

with a minimum follow up for one year and propose the same as a standard, we excluded patients with the following: mid-substance or femoral sided MPFL injuries, recurrent patellar instability, TT-TG distance greater than 25mm, trochlear dysplasia type C and D, multi-ligament injury, habitual dislocators, arthritic changes and age more than 50 years. 17 patients who were managed for recurrent patellar instability i.e., those with at least one prior episode of patellar instability and 13 patients with higher grades of trochlear dysplasia i.e. Types C and D were also excluded. Five case sheets had incomplete data, and two patients were lost to follow up. The remaining 30 patients with acute primary patellar sided MPFL avulsion injuries were categorized into five groups (P_0- P_4) by extending the classification of Sillanpää et al[12].

Injury characteristics:

Five patterns of patellar sided MPFL injuries were recognized on MRI scans and at surgery. P_0 is either a purely ligamentous disruption of MPFL at its patellar attachment or an insignificant bony avulsion of MPFL from the medial patellar margin with fragment size < 1 cm, P_1 is a bony avulsion fracture of MPFL from the medial patellar margin with fragment size >1 cm, P_2 is bony avulsion including articular cartilage from the medial patellar facet, P_3 with an independent significant chondral fragment (>1 cm) from the medial patellar facet with either an intact lax or disrupted MPFL and P_4 with ligamentous disruption of MPFL at the patellar attachment and an insignificant intra-articular loose osseous, chondral or osteochondral fragment (<1 cm). These have been diagrammatically represented in (Figure 1) and axial MRI images representing the same shown in (Figure 2). Based on trochlear morphology, seventeen patients had type A dysplasia, 5 patients had type B dysplasia, and 8 patients had normal morphology[14-16].

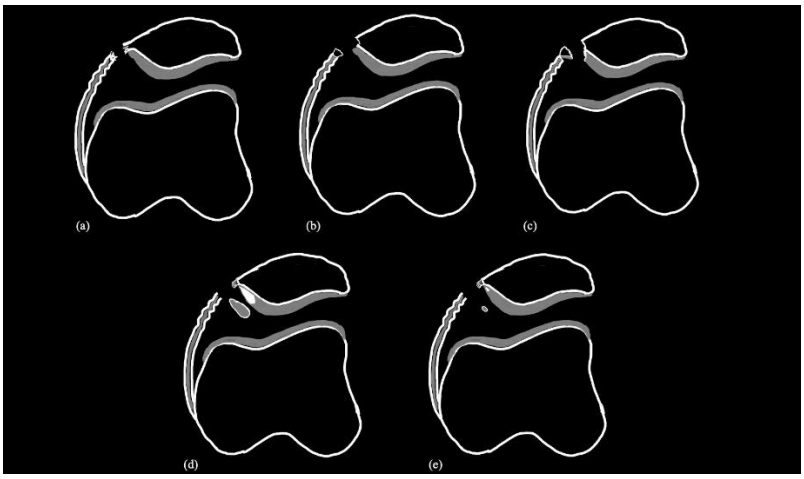

Figure 1. Types of Patellar sided MPFL avulsion injuries.

(a) P_0 with purely ligamentous detachment of MPFL at patellar attachment
(b) P_1 with bony avulsion fracture (>1 cm) of MPFL from the medial patellar margin
(c) P_2 showing bony avulsion including articular cartilage from the medial patellar facet
(d) P_3 with an independent significant chondral fragment (>1 cm) from the medial patellar facet with either an intact lax or disrupted MPFL
(e) P_4 with ligamentous disruption of MPFL at the patellar attachment and an insignificant intra-articular loose body

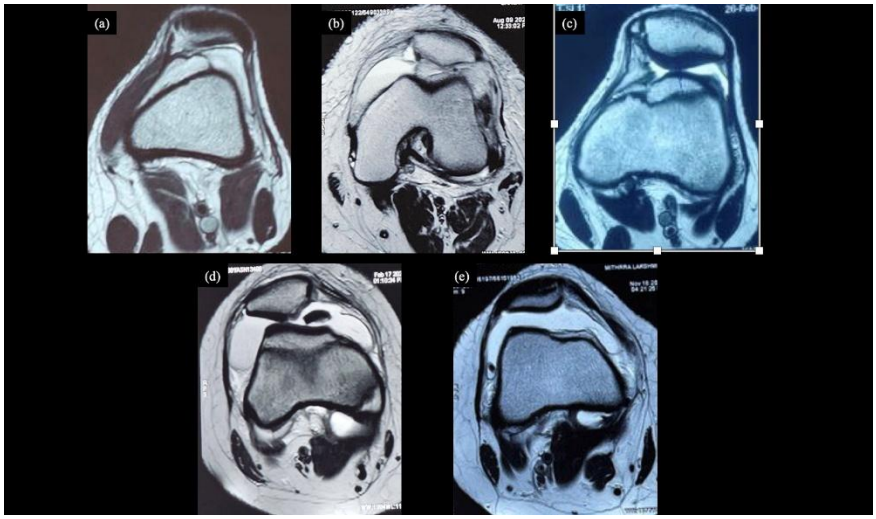

Figure 2. Axial MRI images showing MPFL avulsion injuries.
(a) P_0 with purely ligamentous MPFL disruption
(b) P_1 with significant bony avulsion of MPFL and an intra-articular loose body
(c) P_2 with bony avulsion including articular cartilage from medial patellar facet
(d) P_3 with a significant chondral fragment and an intact lax MPFL
(e) P_4 with an intra-articular loose body and disrupted MPFL

Treatment protocol:

Nine patients with P_0 type injury were managed conservatively while three patients with P_1 and two patients with P_2 type injuries underwent fixation of the avulsed fragment with the intact MPFL and MPFL augmentation done. Five patients with P_3 type injury underwent suture bridge fixation of the chondral fragment, along with MPFL reconstruction or augmentation. In the eleven patients with P_4 type injury, the loose fragment (<1 cm) was removed and MPFL reconstruction done.

Surgical technique:

All patients requiring surgery underwent initial standard diagnostic arthroscopy and the extent of osteochondral damage evaluated. Patients with P_1, P_2 and P_3 type injuries underwent open reduction and fixation of osteochondral or chondral fragments through a 3 cm long incision along the medial patellar border. Sharp dissection was done to expose the anterior surface of the medial third of the patella.

In P_1 and P_2 type injuries, deep dissection was done to identify the osseous or osteochondral fragment, edges freshened and fragment fixed anatomically with 2 FiberWire, using suture bridge technique, by taking suture bites in the medial retinaculum and through the soft tissue flap that was raised in the anterior aspect of patella and knots tied anteriorly as shown in (Figure 3). Though these patients had no evident ligamentous disruption of the MPFL on imaging,taking into account any plastic deformation of the medial soft tissue structures following injury [17], we augmented the repair by performing an MPFL reconstruction i.e., MPFL augmentation.

In patients with P_3 type injury, medical arthrotomy was performed, the significant chondral fragment removed, edges of the cartilage bed freshened, fragment reduced anatomically and fixed using suture bridge technique as shown in (Figure 4). This was followed by MPFL reconstruction or augmentation.

All MPFL reconstruction or augmentation procedures were performed using the transosseous single loop suture technique using Gracilis autograft published by Sahanand et al[18].

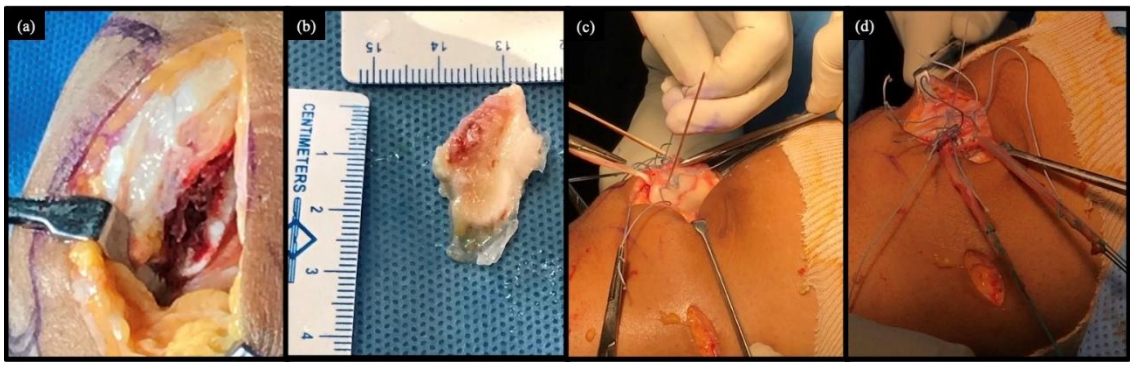

Figure 3. Surgical steps in management of P_2 injury.

(a) Intra operative picture of P_2 injury
(b) Osteochondral P_2 fragment measuring 2.5 cm in its largest dimension
(c) Osteochondral fragment reduced anatomically using suture bridge technique
(d) Knots tied anteriorly over soft tissue covering patella

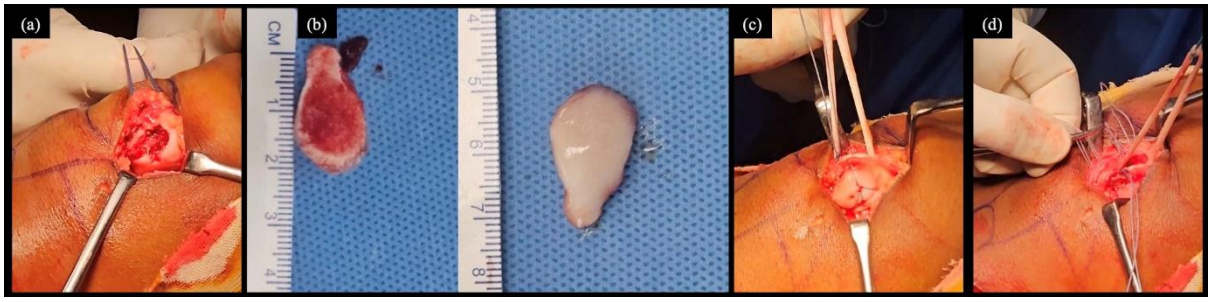

Figure 4. Surgical steps in management of P_3 injury.

(a) Intra operative picture of chondral defect in medial patellar facet in a P_3 injury
(b) Dimensions of the P_3 chondral fragment measuring 2 cm in its largest dimension
(c) Chondral fragment reduced anatomically using suture bridge technique
(d) Knots tied anteriorly over soft tissue covering patella

Statistical methods:

The statistical analysis in this study was designed to evaluate the clinical outcomes of a treatment-based classification protocol for patellar-sided MPFL avulsion and included repeated measures ANOVA, Bonferroni post-hoc tests, and subgroup comparisons. Descriptive statistics were used to summarize demographic and clinical characteristics, including age, sex, trochlear dysplasia type and injury classification. Continuous variables like age and Kujala scores were expressed as mean ± standard deviation and range, while categorical variables were represented by frequency and percentage. The effectiveness of the treatment over time was assessed using repeated measures ANOVA. A "p"value less than 0.05 was considered as statistically significant. Data analysis was performed using open-source statistical software Jamovi 2.6.26, Sydney, Australia.

Results:

The mean age of presentation of the study population was 18.2 years (±5.4), with the age range extending from 13 to 37 years. Out of the 30 patients included in the study, 63.3% were female and remaining were

male. Based on trochlear morphology, 56.7% patients had type A dysplasia, and 16.7% patients had type B dysplasia while 26.7% of patients had a normal trochlear groove. This reveals that the majority of patients with lateral patellar instability had some form of trochlear dysplasia. The percentage distribution according to the type of patellar sided MPFL injury showed that P_4 injuries are the most common (36.7%), followed by P_0 (30%), P_3 (16.7%), P_1 (10%) and P_2 (6%) as shown in (Table 1).

The progressive increase in the Kujala scores at four key time points: baseline, at 3 months, 6 months and 1year follow-ups showed that there was a steady and statistically significant improvement from a mean baseline score of 58.6 (±17) to 96.2(±2.4) at 1 year as shown in (Table 2). The interquartile range (IQR) also narrowed over time, indicating more uniform improvement among patients. This trend demonstrates the overall effectiveness of the treatment protocol in restoring knee function and reducing instability-related symptoms over time. Thus, the primary determinant of functional recovery was time, not the treatment modality itself, underscoring that the critical step to a successful outcome is the initial, classification-guided decision. This work provides a strong foundation for adopting a more sophisticated and individualized treatment paradigm for patients with acute primary lateral patellar instability.

The repeated measures ANOVA reveals a highly significant effect of time on Kujala scores ($F(3,87) = 102.1$, $p < 0.001$), confirming that the patients experienced a consistent and significant improvement across each time point. The large sum of squares (SS = 23045) and high F-value validate the robust effect of the treatment protocol across the cohort regardless of the individual variations in procedure type.

Bonferroni's post-hoc analysis demonstrates that all time point comparisons showed statistically significant improvements ($p < 0.001$), including early vs. later outcomes (i.e., Pre-op vs 3 months, 6 months, and 1 year), as well as between consecutive postoperative phases. The most substantial mean difference (−37.5) was between preoperative and 1-year follow-up scores. Even shorter intervals, such as 3-month to 6-month (−8.3) and 6-month to 1-year (−9.2), revealed continued improvement, emphasizing progressive functional recovery post-treatment.

On comparing mean Kujala scores at each time point between the conservative (n=9) and surgical (n=21) groups, it is seen that both groups began with nearly identical preoperative scores (~58.6), and the improvement over time was parallel. By 1 year, both groups reached high functional levels,with scores of 95.6 (±2.8) and 96.4 (±2.2) for conservative and surgical groups, respectively, as seen from (Figure 5-6). This suggests that while surgery was necessary for more complex injuries, conservative management was also effective in selected cases. This finding reinforces the importance of appropriate patient stratification and the effectiveness of our treatment protocol based on injury classification. By the end of one year, there were no patients with recurrent patellar instability in our study population.

Table 1. Distribution of patellar sided MPFL avulsion injuries

Type of Patellar sided MPFL avulsion	Frequency	Percent
P_0	9	30
P_1	3	10
P_2	2	6.7
P_3	5	16.7
P_4	11	36.7
Total	30	100

Table 2. Kujala Scoring at Different Time Points

Time point	N	KUJALA SCORING			
		mean ± SD	Range	Median	Inter-Quartile Range
Baseline	30	58.6 ± 17	20 - 76	63	57 - 71
3 months follow up	30	78.7 ± 5.2	67 - 87	80	76 - 83
6 months follow up	30	87 ± 3.5	80 - 93	87	84 - 89.25
1 year follow up	30	96.2 ± 2.4	91 - 100	97	95 - 97

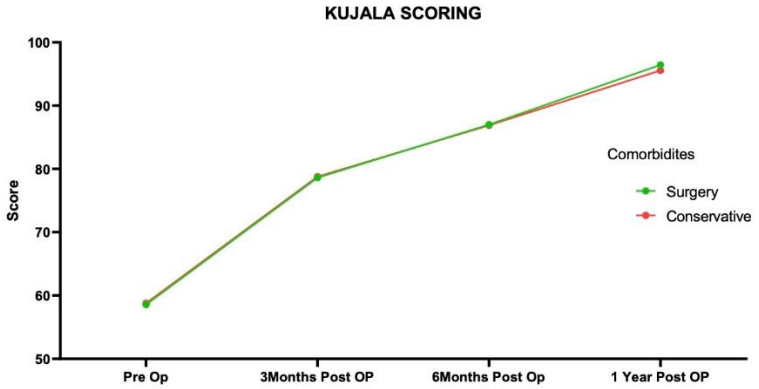

Figure 5. Kujala scores different time points in conservatively managed and surgically treated groups.

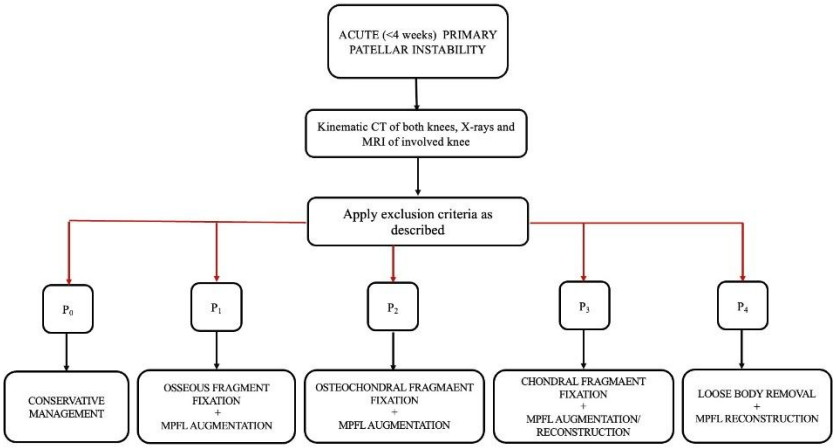

Figure 6. Flowchart illustrating treatment algorithm for acute primary patellar side MPFL injuries.

Discussion:

This retrospective study aims to re-define the characteristics of patellar sided MPFL avulsion injuries and propose a new treatment-based classification for such injuries. There was a striking concentration of patients in the adolescent age group of 13–16 years, which constituted half of the entire cohort (50%, n=15). This reinforces that patellar instability is common in adolescence, a period characterized by rapid growth and high levels of physical activity, which increase the risk of a primary dislocation event. The study also observed a significant female predominance, with female patients accounting for 63.3% (n=19) of the cohort compared to 36.7% (n=11) for males. This two-to-one ratio is consistent with the broader literature, which often attributes this disparity to factors such as generalized ligamentous hyperlaxity, a wider pelvis leading to a greater Q-angle, and other anatomical variations more common in females [(2)]. These baseline demographic characteristics confirm that the study population is representative of a typical cohort presenting with primary patellar instability,thereby enhancing the generalizability of the subsequent findings.

The core of this study's proposed innovation lies in the use of a modified Sillanpää classification to characterize the specific pattern of patellar sided MPFL avulsion injuries. Patellar MPFL avulsion injuries were classified into five categories from P_0 to P_4 as previously described. The treatment protocol for each of these types of injury is represented in the form of a flowchart in (Figure 6). The distribution of injury grades was heterogeneous, which supports the need for such a classification. The wide spectrum of injury patterns, from purely ligamentous MPFL injury to a combination of ligamentous with osseous,chondral or osteochondral fragments of varying sizes, underscores the need for individualized treatment approaches. The treatment allocation presented in this study directly reflects the application of this treatment-based classification-guided philosophy. This tailored approach is central to the study's objective of evaluating a more sophisticated management strategy than simply choosing between "conservative management" and "MPFL reconstruction."

The primary functional outcome, as measured by the Kujala score [(19)], demonstrated a statistically significant improvement over the one-year follow-up period for the entire cohort. The findings provide a comprehensive overview of the efficacy of a stratified treatment approach, comparing both conservative and surgical management for acute primary lateral patellar instability. In contrast to the clinical outcomes published in the study by Sillanpää et al [(12)], where two patients had recurrent patellar instability despite fragment fixation, we have achieved good results in our study. This may be attributed to the MPFL augmentation procedure performed in such patients who would have otherwise undergone fragment fixation only. In his original paper, E. Nomura observed a lax MPFL without any macroscopically observable injury, following an acute patellar dislocation [(17)] in one patient, which may lead to a non-functional structurally intact MPFL. Hence in our study, MPFL reconstruction was performed in all patients requiring surgical intervention and even in those patients where the continuity

of the medial check rein could have been established with fragment fixation alone. MPFL augmentation refers to the reconstruction of MPFL using standard techniques [18], in patients with a lax and potentially ineffective medial soft tissue structures following injury.

The results strongly suggest that this treatment protocol leads to significant and consistent functional improvements across the entire patient cohort, which is evident from the fact that the conservative group also demonstrated significant functional gains at each time point (p-values ranging from 0.036 to 0.001), although with slightly larger standard errors due to smaller sample size. These results reinforce that both conservative and surgical treatment modalities yielded significant clinical improvement in well-selected patients, aligning with the study's objective of evaluating a treatment-based classification approach. Moreover, the absence of recurrent instability at one year is an important finding which supports that the proposed classification system and treatment algorithm could enhance the outcomes in the management of acute patellar instability.

Limitations:

This is a retrospective cohort study. All surgical procedures were performed by a single fellowship trained senior knee consultant and hence caution to be exercised before over generalization of the results of the outcomes of the surgical procedures and the resultant functional outcomes. Prospective studies with larger cohorts and longer follow ups may help strengthen the evidence of this treatment-based classification.

Conclusion:

Acute primary patellar sided MPFL injuries can be classified into five types P_0, P_1, P_2, P_3 and P_4 based on injury pattern and associated pathology (e.g., loose bodies or significant osseous, chondral or osteochondral damage) which can guide decision-making for the type of management. Patients with P_1 to P_4 injuries benefitted from acute surgical repair as evidenced by the absence of recurrent instability and higher Kujala scores. MPFL augmentation significantly improved clinical outcomes. With this tailored treatment protocol, all patients experienced progressive functional recovery, validating the effectiveness of the treatment protocol proposed in this study.

Conflict of interest:

Nil

Financial support and sponsorship:

Nil

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