Medial Patellofemoral Ligament Injury. Location-Based Rate of Recurrent Patellar Dislocation After Non-Operative Treatment

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1  Medial Patellofemoral Ligament Injury. Location-Based Rate of Recurrent Patellar Dislocation After Non-Operative Treatment
Abstract

Objectives: The role of the medial patellofemoral ligament (MPFL) as a patellofemoral joint stabilizing structure is undisputable. After traumatic patellar dislocation, MPFL injury, together with bone edema in the medial patellar facet and lateral femoral condyle, is a pathognomonic finding in magnetic resonance imagine. MPFL injury in the femoral insertion has been reported to most likely predict recurrent dislocations. The objective of this study was to detect if any MPFL injury location predicts the earliest onset of the patellar re-dislocation.

Methods: In total, 64 eligible patients with a first-time traumatic patellar dislocation were recruited to the trial. The diagnosis was confirmed within three weeks with 3 Tesla magnetic resonance imaging (MRI). The location of the MPFL injury in MRI was localized at the patellar insertion, midsubstance area, femoral insertion, or a combination of these. During the three-year follow-up period, patellar re-dislocations, range of motion, quadriceps muscle atrophy, and daily symptoms were determined. All the patients were treated non-operatively.

Results: Out of 64 patients, 33 (51.6%) had at least one episode of patellar re-dislocation. Re-dislocations occurred in 8 out of 25 (32.0%) patients with the main injury at the femoral insertion, 5 out of 15 (33.3%) patients with the main injury at the midsubstance area, and 10 out of 24 (41.7%) patients with the main injury at the patellar insertion during the 36 months follow-up (p=0.758). According to Kaplan-Meier analysis, the location of MPFL injury did not have statistically significant effect on timing of re-dislocations. At 36 months, survival of patients with MPFL injury at the patellar insertion was 70.8%, which was not statistically significantly different than the survival in patients with injury at the femoral insertion (88.0%) or at the midsubstance area (93.3%). No differences between single and multiple MPFL injuries were found. At 4 weeks, range of motion was more restricted in patients with MPFL injury at the femoral insertion (93.4° vs. 108.0° for injury at the midsubstance area and 107.7° at the patellar insertion).
Conclusion: The location of MPFL injury did not have statistically significant effect on timing or rate of re-dislocations. The MPFL injury at the femoral insertion predicts decreased ROM of the knee and increased quadriceps muscle atrophy during the first three months after sustaining injury.

Key Terms: Traumatic patellar dislocation, recurrent patellar dislocation, patellar re-dislocation rate, MPFL injury location.

Level of Evidence: Level III.

What are the new findings:

1) At 4 weeks, range of motion was more restricted in patients with medial patellofemoral ligament injury at the femoral insertion.

2) Patellar re-dislocation rate was not different between single and multiple medial patellofemoral ligament injuries.

3) The location of medial patellofemoral ligament injury did not have statistically significant effect on timing of re-dislocations.
Introduction

Acute traumatic lateral patellar dislocation (LPD) is a common injury in adolescents and young adults [1-3]. For treatment of primary patellar dislocation, nonoperative management has been suggested in patients with no concomitant injuries such as osteochondral fractures [4-10]. However, the risk for re-dislocation after non-operatively treated traumatic LPD is reported to be 20%-60% [1, 2, 4, 9, 11]. In addition to re-dislocation, patients may have several other short- and long-term sequelae after acute LPD, such as decreased range of motion (ROM), quadriceps muscle atrophy, deterioration of the patellofemoral cartilage, or symptoms during daily activity [7, 12].

Predisposing anatomical risk factors for recurrent LPD include patella alta, trochlear dysplasia, increased distance between tibial tubercle and femoral trochlear groove, and excess femoral anteversion [1, 13-18].

Diagnosis of LPD is verified with magnetic resonance imaging (MRI). Medial patellofemoral ligament (MPFL) injury and bone edema in the medial patellar facet and lateral femoral condyle are pathognomonic for traumatic LPD [19-21]. After traumatic LPD, cartilage lesions in the patellofemoral (PF) joint occur in 71%-95% of patients, and osteochondral fractures are visible in up to 25% of patients [1, 2, 19, 21-23].

The role of the MPFL as a patellofemoral joint stabilizing structure is undisputable [24, 25]. Patellar insertion of the MPFL is at the superior medial border of the patella, and the femoral attachment lies between the adductor tubercle and the medial epicondyle [25-28]. Interestingly, the MPFL provides 50%-80% of the forces required to prevent lateral patellar displacement [25-28]. MPFL injury can be seen in the patellar insertion, midsubstance area, femoral insertion, or in various combinations of these locations [6, 19, 29-31]. In particular, MPFL injury in the femoral insertion has previously been reported to predict patellar instability and recurrent dislocations after traumatic LPD [31].
To our knowledge, no reports concerning the anatomical location of MPFL injury and its association with the timing of patellar re-dislocation have been published. Therefore, the aim of this study was to assess the association between the anatomical location of MPFL injury and the timing of patellar re-dislocations. The hypothesis is that MPFL injury in the femoral insertion predicts earlier onset of the patellar re-dislocation. Furthermore, we also determine the effects of MPFL injury location on ROM, quadriceps muscle atrophy, and daily symptoms during a three-year follow-up period.
Materials and Methods

This study was conducted at XX Hospital between July 2012 and November 2015 as a secondary analysis of a previously published trial [7]. The study was approved as part of previously published trial [7] by the Regional Ethics Committee of XX Hospital, ETL-code R05024. All skeletally mature patients (physes closed) who were admitted to the emergency department with first-time traumatic LPD and no previous patellar instability symptoms in the recently injured knee were eligible for the study. Patients underwent standard x-rays using anteroposterior, medial to lateral, and axial projections. The diagnosis of primary LPD was subsequently confirmed with 3T MRI within the first three weeks after sustaining the injury. The diagnosis of traumatic LPD required typical findings in MRI, which included MPFL injury and bone edema in the medial patellar facet or the lateral femoral condyle. The location of the MPFL injury was localized at the patellar insertion, midsubstance area, femoral insertion, or a combination of these locations (Figure 1). MRI scans were evaluated by experienced musculoskeletal radiologists, but inter- and intra-rate reliability was not determined. For the analyzes, the main injury site was determined. The most damaged zone of MPFL in primary MRI, where no continuum of fibers was not seen, was sentenced as the main injury. Patients with other ligamental injuries, such as anterior or posterior cruciate ligament (ACL, PCL) injury and notable medial or lateral collateral (MCL, LCL) injury, were excluded from the analysis. Patients who underwent urgent surgical treatment due to large osteochondral fragment (2 patients) or recurring LPD (2 patients) during the first four weeks did not attend to the study follow-up (protocol of a previously published trial [7]) and therefore were also excluded from the analyses of this study. Hence, the study population of 64 patients was formed.

All study patients wore a patellar stabilizing brace for the first four weeks after the injury, and they were advised to use crutches for as long as needed. Immediate full weight-bearing was allowed as tolerated. Patients received physiotherapeutic instructions, which included closed chain lower limb and quadriceps muscle strengthening exercises. Contact sports were not recommended for the first
three months after the injury. All study patients visited the outpatient clinic regularly for a period of three years after primary injury [7]. Two orthopedic surgeons with experience of knee injuries were in contact with the patients at follow-up visits. At each follow-up visit, patients were asked about patellar re-dislocations or any instability symptoms in the PF joint. As a re-dislocation was determined anamnestic occurrence of total lateral dislocation of patella and spontaneous or assisted re-location. Elapsed time for patellar re-dislocation was detected. The Kujala score was used as a patient-reported outcome measure [32]. Tegner-score of the study patients was determined at 12, 24 and 36 months after the first-time LPD [33]. Also, pre-injury Tegner score was assessed, providing information about the patients’ pre-existing activity levels. The quadriceps muscle atrophy existence was observed as a clear visible difference between injured and unaffected limb.

Anatomical risk factors for recurrent patellar dislocation were measured from MRIs by one author. Inter- or intraobserver reliability was not determined. Determined anatomical features were tuberositas tibiae - trochlear groove (TT-TG) distance, tuberositas tibiae - posterior cruciate ligament (TT-PCL) distance, trochlear depth, sulcus angle and lateral inclination angle.

Measurements were done using accurately documented and illustrated methods described by Arendt et al. [34]. The patients without patellar re-dislocations and patients with one or more total re-dislocation were compared according to the anatomical variations.
Statistical analysis

The Kaplan-Meier method was used to study the survival of the knee joint using re-dislocation as an endpoint. Stratified analysis was done based on the injury location. Further, a crude comparison between continuous variables was made using either two-sample t-test or ANOVA. Repeated-measure analysis using a mixed-model repeated-measures analysis of variance was performed. Location of injury was used as a grouping variable and used in addition to time of assessment as fixed factors. Patients were used as random factors. The model included interactions between groups and time of assessment. Further, the model was used to assess the absolute difference between the injury groups in ROM and Kujala score (mean and 95% CIs) and the p-value at each time point. Satterthwaite methods were used to estimate degrees of freedom. Analyses were done using SPSS version 28 and RStudio (R Core Team, Vienna, Austria) with lmer package.

The sample size calculation was conducted for the purposes of previously published trial [7] where 27 patients per group were evaluated to be needed to achieve a power of 80% with 5% type I error level. Assuming a 20% drop-out rate, the sample size was set at 32 patients per group. Therefore, sample size of 64 patients for this present study was formed.
Results

In total, 64 eligible patients with primary LPD were recruited to the trial after sustaining primary traumatic patellar dislocation [7]. Mean age of the study patients was 26 years (range 15-52 years) and 29 out of 64 patients (45.3%) were male (Table 1). The diagnosis of traumatic LPD (MPFL injury and bone edema in the medial patellar facet or the lateral femoral condyle) was confirmed with 3T MRI (Table 2). Osteochondral fractures and patellar bony avulsion injury were also determined. In addition, anatomical risk factors for recurrent patellar dislocation were assessed (Table 3). Trochlear depth, sulcus angle and lateral inclination angle were statistically significantly lower in patients with patellar re-dislocations (mean differences 0.9 mm, 5.8 degrees and 2.5 degrees; p<0.001, p<0.001 and p=0.002, respectively). No other statistically significant difference between the groups was detected.

All patients had sustained an MPFL injury in at least one MPFL location and 46.9% had visible injuries in more than one location. MPFL injury at femoral insertion was seen in 32 out of 64 patients (50%), in patellar insertion 37 out of 64 patients (58%) and in midsubstance zone in 34 out of 64 patients (53%) (Table 2). Correlation between the determined anatomical risk factors and main MPFL injury location was analyzed using ANOVA-analysis. No statistically significant difference between the groups was found (Table 4).

Patient Characteristics

<table>
<thead>
<tr>
<th>n=64</th>
</tr>
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Mean age (standard deviation, range) 26.1 (9.0, 15.2-52.0)
<table>
<thead>
<tr>
<th>Sex</th>
<th>29 (45.3%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male, %</td>
<td>29 (45.3%)</td>
</tr>
<tr>
<td>Female, %</td>
<td>35 (54.7%)</td>
</tr>
<tr>
<td>Mean pre-injury Tegner score</td>
<td>5.81 (1.1, 2-8, 1.0)</td>
</tr>
</tbody>
</table>

Table 1. Patient characteristics for the description of the study population. The study group consisted of 64 patients with first-time acute lateral patellar dislocation.

**Magnetic resonance imaging findings**

<table>
<thead>
<tr>
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<th>n=64</th>
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<tbody>
<tr>
<td>Osteochondral fragment</td>
<td>5 (7.8%)</td>
</tr>
<tr>
<td>(small, non-operative) (%)</td>
<td></td>
</tr>
<tr>
<td>Patellar avulsion fragment</td>
<td>14 (21.9%)</td>
</tr>
<tr>
<td>(%)</td>
<td></td>
</tr>
<tr>
<td>Cartilage lesion in patellofemoral joint (%)</td>
<td>31 (48.4%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Medial patellofemoral ligament injury location</th>
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<tbody>
<tr>
<td>Patellar insertion (%)</td>
<td>37 (57.8%)</td>
</tr>
<tr>
<td>Midsubstance (%)</td>
<td>34 (53.1%)</td>
</tr>
<tr>
<td>------------------</td>
<td>------------</td>
</tr>
<tr>
<td>Femoral insertion (%)</td>
<td>32 (50.0%)</td>
</tr>
<tr>
<td>Combination (%)</td>
<td>30 (46.9%)</td>
</tr>
</tbody>
</table>

Table 2. Traumatic findings in magnetic resonance imaging after primary lateral patellar dislocation. After first-time patellar dislocation, the location of medial patellofemoral ligament injury in magnetic resonance imaging was determined in femoral, midsubstance, patellar insertion or combination of them. All detected injury locations of each patient are reported.

<table>
<thead>
<tr>
<th>Anatomical Risk Factors</th>
<th>No patellar re-dislocations, n=41</th>
<th>One or more total patellar re-dislocation, n=23</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean tuberositas tibiae - trochlear groove distance, mm (standard deviation)</td>
<td>14.4 (4.0)</td>
<td>14.4 (4.4)</td>
<td>0.490 (0.0)</td>
</tr>
<tr>
<td>Mean tuberositas tibiae - posterior cruciate ligament distance, mm (standard deviation)</td>
<td>22.8 (3.5)</td>
<td>22.4 (4.1)</td>
<td>0.337 (0.4)</td>
</tr>
<tr>
<td>Mean trochlear depth, mm (standard deviation)</td>
<td>3.5 (0.9)</td>
<td>2.6 (0.9)</td>
<td>&lt;0.001 (0.9)</td>
</tr>
<tr>
<td>Anatomical Risk Factor</td>
<td>Medial patellofemoral ligament injury location:</td>
<td>Medial patellofemoral ligament injury location:</td>
<td>Medial patellofemoral ligament injury location:</td>
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<tr>
<td>------------------------</td>
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</tr>
<tr>
<td>Mean sulcus angle, degrees (standard deviation)</td>
<td>153.6 (6.4)</td>
<td>159.4 (5.0)</td>
<td>&lt;0.001 (5.8)</td>
</tr>
<tr>
<td>Mean lateral inclination angle, degrees (standard deviation)</td>
<td>15.4 (3.7)</td>
<td>12.9 (2.4)</td>
<td>0.002 (2.5)</td>
</tr>
</tbody>
</table>

Table 3. Determined anatomical risk factors for lateral patellar dislocation. Magnetic resonance imagines of 64 study patients after the first-time traumatic lateral patellar dislocation were evaluated. Included anatomical risk factors was determined. The patients without patellar re-dislocations and patients with one or more total re-dislocation were compared according to the anatomical variations. Trochlear depth, sulcus angle and lateral inclination angle were statistically significantly lower in patients with patellar re-dislocations. No other statistically significant difference between the groups was not detected.
<table>
<thead>
<tr>
<th></th>
<th>Patellar insertion, n=24</th>
<th>Midsubstance, n=15</th>
<th>Femoral insertion, n=25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean tuberositas tibiae - trochlear distance, mm (standard deviation)</td>
<td>14.8 (4.1)</td>
<td>13.3 (4.2)</td>
<td>14.8 (4.1)</td>
</tr>
<tr>
<td>Mean tuberositas tibiae - posterior cruciate ligament distance, mm (standard deviation)</td>
<td>23.5 (3.4)</td>
<td>20.8 (4.2)</td>
<td>23.0 (3.5)</td>
</tr>
<tr>
<td>Mean trochlear depth, mm (standard deviation)</td>
<td>3.1 (1.0)</td>
<td>3.2 (0.8)</td>
<td>3.2 (1.1)</td>
</tr>
<tr>
<td></td>
<td>Mean sulcus</td>
<td>Mean lateral</td>
<td></td>
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<td>----------------------</td>
<td>-------------</td>
<td>--------------</td>
<td></td>
</tr>
<tr>
<td>angle, degrees</td>
<td>157.5 (6.6)</td>
<td>13.6 (3.6)</td>
<td></td>
</tr>
<tr>
<td>(standard deviation)</td>
<td>153.8 (5.1)</td>
<td>15.3 (3.8)</td>
<td></td>
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<td></td>
<td>155.1 (6.8)</td>
<td>15.0 (3.1)</td>
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<tr>
<td></td>
<td>0.187 (3.7)</td>
<td>0.245 (1.7)</td>
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</table>

Table 4. ANOVA-analysis between determined anatomical risk factors and main medial patellofemoral ligament injury location. The study group consists of 64 patients with first-time acute lateral patellar dislocation. After first-time patellar dislocation, the location of medial patellofemoral ligament injury in magnetic resonance imaging was determined in femoral, midsubstance or patellar insertion. Magnetic resonance imaging of 64 study patients after the first-time traumatic lateral patellar dislocation were evaluated. Included anatomical risk factors was determined. Correlation between the determined anatomical risk factors and main medial patellofemoral ligament injury location was analyzed. No statistically significant differences between the groups were found.

Patellar re-dislocation

During the three-year follow-up period, 33 out of 64 (51.6%) patients had at least one episode of patellar re-dislocation. The mean follow-up of the patients was 39.1 months (range 23.4-65.5 months). The mean time for patellar re-dislocation of patients with the MPFL injury at the femoral
insertion was 25.0 months (range 5.5-23.5 months, SD 24.9), 42.6 months (range 17.2-60.7 months, SD 11.9) when the MPFL injury was at the patellar insertion (p=0.321). According to Kaplan-Meier analysis, at 36 months after the initial injury, survival of patients with MPFL injury at the femoral insertion was 88.0% (95% CI: 0.75-1.01), patients with MPFL injury at the midsubstance area 93.3% (95% CI: 0.81-1.06), and patients with injury at the patellar insertion 70.8% (95% CI: 0.53-0.89) (p=0.689) (Figure 2). Re-dislocations occurred in 8 out of 25 (32.0%) patients with the main injury at the femoral insertion, 5 out of 15 (33.3%) patients with the main injury at the midsubstance area, and 10 out of 24 (41.7%) patients with the main injury at the patellar insertion during the 36 months follow-up (p=0.758).

Furthermore, 30 out of 64 (46.9%) patients had MPFL injury after first-time LPD in more than one location. Of these, 11 out 30 (36.7%) patients with MPFL injury in multiple locations had patellar re-dislocation during the three-year follow-up period. In total, 12 out of 34 (35.3%) patients with MPFL injury in a single location (the femoral insertion, midsubstance, or patellar insertion) had patellar re-dislocation. No statistically significant differences between the groups were found (p=0.909). Patients with MPFL injury in a single location had an event of re-dislocation mean of 31.2 months after the primary injury (SD 19.4), whereas patients with MPFL injury in multiple locations had a mean of 26.3 months (SD 17.6). Mean difference between the groups was 4.9 months (95% CI: -14.7 to 24.6, p=0.498).

Range of motion

ROM was measured at 4 weeks and thereafter at 3, 6, 12, 24, and 36 months. At 4 weeks, mean ROM of the injured knee was 93.4º (SD 29.1) when MPFL injury location was at the femoral insertion, 108.0º (SD 26.5) when MPFL injury was at the midsubstance area, and 107.7º (SD 29.1)
when the injury was at the patellar insertion. Statistically significant difference was found. The mean difference between the femoral insertion and the midsubstance area was 14.6° (p=0.01) and 14.2° (p<0.01) between the femoral and patellar insertion. No statistically significant difference was found at 3 months or at any other time point (Figure 3).

Kujala score

The Kujala score [32] of the study patients was determined at 3, 6, 12, 24, and 36 months. An analysis was conducted in relation to the MPFL injury location of the femoral, midsubstance, or patellar insertion. Kujala score at 3 months after traumatic lateral patellar dislocation was 84.0 out of 100 points (SD 10.2) when the MPFL injury was at the femoral insertion, 85.4 at the midsubstance area (SD 10.4), and 85.9 (SD 9.6) at the patellar insertion. No statistically significant difference could be found at 3 months or at any other time point (Figure 4).

Quadriceps muscle atrophy

Quadriceps muscle atrophy was observed at 4 weeks and 3, 6, and 12 months. Atrophy was seen in 40 patients out of 64 (62.5%) at 4 weeks and 3 months, in 20 out of 64 (31.3%) at 6 months, and in 6 out of 64 (9.38%) at 12 months. At 4 weeks and 3 months, 19 out of 40 (47.5%) patients with quadriceps muscle atrophy had MPFL injury at the femoral insertion, 8 out 40 (20.0%) patients at the midsubstance area, and 13 out of 40 (32.5%) at the patellar insertion. No statistically significant difference could not be found at four weeks after the injury (p=0.186) or any other time points during the follow-up.

Tegner-score
At 12 months, mean Tegner-score of the patients with the MPFL injury at femoral insertion was 5.22 (SD 1.1), injury at midsubstance area 4.54 (SD 1.4) and at patellar insertion 5.3 (SD 1.1), p=0.141. Respectively, mean Tegner-scores at 24 months were 5.6 (SD 1.2) (femoral injury of MPFL), 5.5 (SD 0.9) (midsubstance area injury of MPFL) and 5.5 (SD 1.3) (patellar insertion injury of MPFL), p=0.994. At 36 months, mean Tegner-scores were 5.7 (SD 0.9) (femoral insertion injury of MPFL), 5.1 (SD 1.8) (midsubstance area injury of MPFL) and 5.2 (SD 1.6) (patellar insertion injury of MPFL), p=0.375. No statistically significant difference was found in any time point. Pre-injury Tegner-score of all study patients together was 5.8 (SD 1.0) (Table 1).

At 12 months, the mean change in Tegner-score from pre-injury level of the patients with the MPFL injury at femoral insertion was 0.5 points (SD 0.8), injury at midsubstance area 1.1 (SD 1.0) and at patellar insertion 0.8 (0.9), p=0.154. Respectively, at 24 months mean changes were 0.1 (0.6) (femoral insertion injury of MPFL), 0.3 (0.5) (midsubstance area injury of MPFL) and 0.7 (SD 1.2) (patellar insertion injury of MPFL), p=0.099. At 36 months, mean change in Tegner-scores were 0.1 (SD 0.4) (femoral insertion injury of MPFL), 0.3 (SD 1.2) (midsubstance area injury of MPFL) and 1.0 (SD 1.4) (patellar insertion injury of MPFL), p=0.012.
Discussion

A previously reported patellar re-dislocation rate of 20%-60% after non-operatively treated first-time traumatic LPD is in line with the rate seen in this study (33 out of 64 patients, 51.6%) [1, 2, 4, 9, 11]. In the present study, re-dislocations occurred in 8 out of 25 (32.0%) patients with the main injury at the femoral insertion, 5 out of 15 (33.3%) patients with the main injury at the midsubstance area, and 10 out of 24 (41.7%) patients with the main injury at the patellar insertion during the 36 months follow-up. This finding differs from previously reported results, where MPFL injury at the femoral insertion has been reported to be the most predictable factor for patellar re-dislocation [31]. Further, the location of MPFL injury did not have statistically significant effect on timing of re-dislocations. At 36 months, survival of patients with MPFL injury at the patellar insertion was 70.8%, which was not statistically significantly different than the survival in patients with injury at the femoral insertion (88.0%) or at the midsubstance area (93.3%).

In total, 30 out of 64 (46.9%) patients had MPFL injury after first-time LPD in more than one location. This is a slightly higher portion than the previously reported multiple site MPFL injuries (22.5%-45.0%) [35-37]. However, when the incidence or time to re-dislocation between patients with MPFL injury in single and multiple locations were analyzed, no statistically significant difference was found.

According to the findings of this study, MPFL injury at the femoral insertion results in statistically more significant decrease in ROM at 4 weeks after the injury in the affected knee than injury at the midsubstance area or the patellar insertion (mean difference 14.6° and 14.3°). Furthermore, at 4 weeks and 3 months, patients with MPFL injury located at the femoral insertion had quadriceps muscle atrophy considerably more often than patients with MPFL injury at the midsubstance or the patellar insertion. However, no statistically significant difference could be detected. The combination of decreased ROM and atrophied quadriceps muscle could be considered as discomfort.
causing symptoms, even though the patient-reported outcome measure, the Kujala score, could not reveal any statistically significant differences. Further, physical activity representational Tegner score was not statistically different at any follow-up time points when three MPFL injury locations were compared. However, after 36 months of follow-up, the decrease in Tegner-score was statistically significantly bigger in patients with MPFL injury in patellar insertion than in femoral insertion or midsubstance are (mean difference 1.0 versus 0.1 and 0.0, respectively).

The clinical significance of MPFL as a patellofemoral joint stabilizing structure is undisputable. Moreover, the MPFL provides 50%-80% of the forces required to prevent lateral patellar displacement [25-28]. Thus, injury to the MPFL may cause an increased risk for patellar re-dislocations. MPFL reconstruction is a widely used method of operative treatment, while non-operative treatment is often recommended [1, 6, 31, 38]. However, the re-dislocation rate after non-operative treatment reported in this study (51.6%) and previous studies (20-60%) is quite remarkable. Therefore, highly active younger adults or professional athletes might benefit operative treatment [39]. Therefore, it would be beneficial to identify those factors that lead to poorer outcomes after non-operative treatment. Sillanpää et al [31] reported of an increased risk for patellar re-dislocations when the MPFL injury was seen in the femoral insertion. The purpose of the present study was to reveal MPFL injury location which would predict the earliest onset of patellar re-dislocation and therefore help decision making of clinicians. However, in this study, we could not detect any statistically significant difference between MPFL injury location and the rate or timing of patellar re-dislocations. On the other hand, according to our findings, MPFL injury at the patellar insertion predicts decreased range of motion during the first month after sustaining the injury.

Furthermore, widely described predisposing anatomical risk factors may increase the risk for recurrent LPD [1, 13-18, 24, 25]. We analyzed the correlation between the determined anatomical risk factors (sulcus depth, sulcus angle and sulcus inclination angle, increased distance between tibial tubercle and femoral trochlear groove, and increased distance between tibial tubercle and PCL
insertion) and the main MPFL injury location. Patients with patellar re-dislocations (51.8%) had more findings of trochlear dysplasia (lesser trochlear depth, lower sulcus angle and decreased lateral inclination angle) when compared to patients without patellar re-dislocations. However, underlying anatomical variation did not seem to affect the site where the MPFL rupture evolves, while no statistically significant difference between the anatomical risk factors and the MPFL injury location was found in this study. Similar findings have been reported in previous studies, where trochlear dysplasia, patellar height or TT-TG distance had no influence on MPFL injury site or pattern [40]. In one study, however, the MPFL injury rate at the patellar insertion was increased when TT-TG distance was higher [41].

The mean weakness of this study was the relatively small study group of 64 patients. Our study group was originally designed for earlier trial [7] and therefore was not capacious enough to detect statistically significant findings. With larger sample, the effect of MPFL injury locations for the timing of patellar re-dislocation might be found. However, the follow-up time of three years could be considered adequate to detect all the events of patellar re-dislocations and ensure reliable survival analysis. Furthermore, the prospective setting of the study resulted in detailed reports from the study patients and accurate observations from the authors. To our knowledge, such prospective data with three years of follow-up have not previously been published.

Two patients with early re-dislocation during the first four weeks after the initial injury were excluded from the analyzes, according to the protocol and purposes of the original trial where patients were recruited. Another one had the MPFL injury at the femoral insertion and the other in patellar insertion. They both were operated with MPFL reconstruction within a few days after injury because of almost constantly dislocating patella. According to the setting of the original trial, any follow-up data was not collected of excluded patients. The missing data of these two patients could be considered as limitation.
In conclusion, according to the findings of this study, the location of MPFL injury did not have statistically significant effect on timing or rate of re-dislocations. However, the MPFL injury at the femoral insertion predicts decreased ROM of the knee and increased quadriceps muscle atrophy during the first three months after sustaining injury.

Acknowledgements

None.
References


Figure legends

Figure 1. Magnetic resonance imaging after first-time patellar dislocation. The location of the medial patellofemoral ligament injury was localized at the patellar insertion, midsubstance area, or femoral insertion, or a combination of these locations. A) medial patellofemoral ligament injury at the femoral insertion (arrow). B) medial patellofemoral ligament injury at the midsubstance area (arrow). C) medial patellofemoral ligament injury at the patellar insertion (arrow). D) Combined injury considering all locations of the medial patellofemoral ligament.

Figure 2. Kaplan-Meier analysis of patellar re-dislocation and medial patellofemoral ligament injury location of 64 study patients. After first-time patellar dislocation, the location of medial patellofemoral ligament injury in magnetic resonance imaging was determined in femoral, midsubstance or patellar insertion. At 36 months after the initial injury, the survival of patients with
medial patellofemoral ligament injury at the femoral insertion was 88.0% (95% CI: 0.75-1.01),
patients with medial patellofemoral ligament injury at the midsubstance area 93.3% (95% CI: 0.81-
1.06), and patients with injury at the patellar insertion 70.8% (95% CI: 0.53-0.89) (p=0.689).

Figure 3. Range of motion of the injured knee at 4 weeks and 3, 6, 12, 24, and 36 months after
traumatic lateral patellar dislocation by main medial patellofemoral ligament injury location, 1 =
femoral insertion, 2 = midsubstance area, 3 = patellar insertion. Range of motion at four weeks after
initial trauma, mean range of motion was 93.4° when medial patellofemoral ligament injury
location was at the femoral insertion, 108.0° with the injury at the midsubstance area, and 107.7°
with the injury at the patellar insertion. Statistically significant difference was found. The mean
difference between the femoral insertion and the midsubstance area was 14.6° (p=0.01) and
14.2°(p=0.00) between the femoral and patellar insertion. No statistical difference was found at 3
months or at any other time point.

Figure 4. Kujala score [16] at 4 weeks and 3, 6, 12, 24, and 36 months after traumatic lateral
patellar dislocation. Main medial patellofemoral ligament injury location: 1 = femoral insertion, 2 =
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Figure Captions

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Figure 1A. Medial patellofemoral ligament injury at the femoral insertion (arrow).
Figure 1B. Medial patellofemoral ligament injury at the mids substance area (arrow).
Figure 1C. Medial patellofemoral ligament injury at the patellar insertion (arrow).
Figure 1D. Combined injury considering all locations of the medial patellofemoral ligament (arrows).
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Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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