

# Patellofemoral Stabilization

## Postoperative Redislocation and Risk Factors Following Surgery

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**Background:** Patellofemoral instability is a common knee problem that is difficult to manage owing to its multifactorial etiology as well as the fact that predisposing pathoanatomic features vary from individual to individual. There is limited knowledge regarding the demographic and pathoanatomic risk factors or the relationship between these risk factors and the redislocation rate after surgical stabilization for this challenging condition.

**Purpose:** To analyze the postoperative redislocation rates and the prevalence of demographic and pathoanatomic risk factors for patients undergoing a patellofemoral stabilization.

**Study Design:** Case series; Level of evidence, 4.

**Methods:** Patients with symptomatic recurrent patellofemoral instability underwent a soft tissue patellofemoral stabilization procedure. A total of 342 patellofemoral stabilization procedures (reconstruction,  $n = 256$ ; imbrication,  $n = 86$ ) were assessed at a mean follow-up of 24.3 months. Concomitant procedures were performed in accordance with the à la carte concept of addressing significant anatomic or biomechanical characteristics. Two surgical cohorts were analyzed separately for reconstruction or imbrication to address laxity of the medial patellofemoral ligament (MPFL). Failure of the patellofemoral stabilization procedure was defined as postoperative redislocation of the patella. Prevalence of demographic and pathoanatomic risk factors was determined for all patients. Disease-specific patient-reported outcomes were assessed with the Banff Patella Instability Instrument (BPII).

**Results:** A redislocation rate of 5.1% was identified for MPFL reconstruction and 20.9% for MPFL imbrication. For both MPFL procedures, age at time of surgery was significantly younger for the failed group as compared with the intact group. Postoperative BPII scores were significantly lower for patients who subsequently experienced a surgical failure as compared with intact surgery for both MPFL reconstruction ( $P = .048$ ) and MPFL imbrication ( $P = .003$ ).

**Conclusion:** Patellofemoral stabilization with an à la carte approach to surgical selection demonstrated a low postoperative redislocation rate and good clinical results. Younger age at time of surgery was associated with surgical failure. This information may be used to guide surgical decision making and patient education.

**Keywords:** patellofemoral instability; medial patellofemoral ligament; MPFL reconstruction; MPFL imbrication; patellofemoral dislocation; redislocation

Patellofemoral instability is a common knee problem that is frequently associated with pain, decreased activity, reduced quality of life, and long-term osteoarthritis.<sup>11,17,28,30</sup> A complex combination of bony structures as well as active and passive soft tissue restraints works together to stabilize the patella as the knee moves from extension to flexion. The medial patellofemoral ligament (MPFL) is the most influential soft tissue stabilizer, providing passive lateral restraint to the patella. It accounts for up to 60% of the stabilizing forces on the patella.<sup>6,8,14,38</sup>

Addressing the torn or lax MPFL with an MPFL reconstruction (MPFL-R) or MPFL imbrication (MPFL-I) has become widely recognized as a safe and reliable means of reestablishing lateral stability in patients with recurrent lateral patellofemoral instability.<sup>40,47</sup> Procedures such as tibial tubercle osteotomy (TTO), lateral release or lengthening, trochleoplasty, or derotation osteotomy are utilized concomitantly to correct significant anatomic or biomechanical abnormalities.<sup>3,32,46</sup> In patients with recurrent patellofemoral instability, an MPFL-R with or without concomitant procedures has been shown to effectively and consistently improve function and quality-of-life outcomes.<sup>10,21,26,34,37,40,45</sup> Although a few large case series have been published, the information on surgical failure

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rates following MPFL-R has largely been described in systematic reviews. These reviews report a redislocation rate of 1% to 5%.<sup>34,37,40,42,43</sup> For MPFL-I procedures, the failure rate has been reported as 20% to 25%.<sup>1,35</sup>

Patellofemoral instability is difficult to manage owing to its multifactorial etiology, as well as the fact that predisposing pathoanatomic features vary from individual to individual. The heterogeneous nature of the risk factors for patellofemoral instability makes reporting on a truly homogeneous patient population extremely difficult. Given this challenge, there is value in analyzing large cohorts of patients who present with recurrent patellofemoral instability and are treated in a systematic manner.

The primary purpose of this study was to determine the postoperative redislocation rate following patellofemoral stabilization for recurrent lateral patellofemoral instability. The secondary purpose was to characterize and analyze the demographic and pathoanatomic risk factors of the patients with intact and failed surgical procedures.

## METHODS

### Patient Population

This study received ethics approval from the University of Calgary. Between May 2007 and April 2015, a total of 391 knees were diagnosed with recurrent symptomatic patellofemoral instability and underwent a patellofemoral stabilization. Of these, 17 cases had a previous or concurrent cruciate or collateral ligament reconstruction and were excluded from the study. Of the remaining 374 knees that underwent patellofemoral stabilization, 279 received an MPFL-R, and 95 received an MPFL-I.

Patients were evaluated at postoperative 2 years. Any history of redislocation was noted and confirmed by physical examination. Patients who were unable to attend in person for the 2-year follow-up were contacted by telephone and email to determine if they had suffered a redislocation episode. All patients who reported a postoperative dislocation were seen in person to confirm the surgical failure. Banff Patella Instability Instrument (BPII) questionnaires were completed at the clinic visit or online at postoperative 1 and 2 years.

Patients were included for analysis if they had been contacted, in person or by telephone or email, to determine if there had been any postoperative dislocations of the patella. Twenty patients (23 knees) following an MPFL-R

TABLE 1  
Cases With Previous Surgery on the Index Knee<sup>a</sup>

Previous Procedure	MPFL Procedure, n (%)	
	Reconstruction (n = 256 Knees)	Imbrication (n = 86 Knees)
Simple procedure	40 (15.6)	16 (18.6)
Structural change to the extensor mechanism	48 (18.8)	8 (9.3)
Total	88 (34.4)	24 (27.9)

<sup>a</sup>MPFL, medial patellofemoral ligament.

and 9 patients (9 knees) following an MPFL-I could not be contacted for follow-up and were excluded. Therefore, 256 MPFL-R (92% follow-up) and 86 MPFL-I (91% follow-up) procedures were analyzed. The follow-up duration was 24.3 months (range, 20 months–5 years).

Of the included procedures, 112 index knees had undergone previous surgery (Table 1). Concomitant procedures to correct anatomy and alignment of the extensor mechanism were performed in combination with the soft tissue stabilization in 169 cases (Table 2). Simple procedures included minor interventions, such as knee arthroscopy, removal of a loose body, removal of hardware, or meniscal surgery, in which no alteration of the extensor mechanism was undertaken. Procedures that involved structural changes to the anatomy or biomechanics of the extensor mechanism included medial reefing, repair or imbrication of the MPFL, lateral release, repair of a previous lateral release, TTO, trochleoplasty, tibial or femoral osteotomy, and/or patellar tendon shortening.

A single fellowship-trained sports medicine and arthroscopic knee surgeon (L.A.H.) performed all procedures. The clinical indication for surgery was symptomatic recurrent lateral patellofemoral instability. Recurrent lateral instability was diagnosed per detailed patient history and physical examination. All patients reported more than 1 patellofemoral instability episode of dislocation and/or subluxation and had ongoing symptoms of instability that did not respond to standard nonoperative management, including physical therapy and bracing. Patients with corroborating physical evidence of patellar laxity, including but not limited to increased lateral translation of the patella and apprehension to lateral translation, were offered a

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Ethical approval for this study was obtained from the University of Calgary Conjoint Health Research Ethics Board and Child Health Research Office, University of Calgary, Calgary, Alberta, Canada (Ethics ID 24393).



**Figure 1.** Medial patellofemoral ligament reconstruction technique (reproduced with permission from ConMed Linvatec).

stabilization procedure. All patients received soft tissue stabilization, either an MPFL-R or MPFL-I. The decision to perform an MPFL-R or MPFL-I was based on the clinical judgment of the surgeon after thorough assessment of the patient. The majority of patients were offered an MPFL-R; however, those with minimal anatomic risk factors, fewer patellofemoral instability events, and less MPFL laxity were offered an MPFL-I. The premise was that a stretched MPFL with some inherent tissue quality could be successfully shortened by an imbrication, whereas an MPFL with poor tissue quality or substantial laxity would benefit from the more substantial reconstruction procedure. Concomitant procedures were included per the clinical and radiological presentation of the patient. A TTO was considered when the tibial tubercle–trochlear groove (TT-TG) distance was >20 mm and/or there was patella alta with a Caton-Deschamps ratio >1.2. Trochleoplasty was considered when there was Dejour type D trochlear dysplasia.

**Surgical Procedures**

The MPFL-R procedures were performed with a hamstring tendon autograft as previously described by Hiemstra et al.<sup>18</sup> A free hamstring graft was attached to the superior half of the medial border of the patella with suture anchors. A triangular graft was produced, which was attached at the anatomic insertion point on the femur with an interference screw (Figure 1). Intraoperative assessment of the biomechanics of the graft position was performed to ensure that the structures did not tighten in flexion and that the patella was centered in the trochlear groove through the full range of motion of the knee.

The MPFL-I procedures were performed either via the arthroscopic technique described by Halbrecht<sup>13</sup> or through an open procedure with a pants-over-vest method (Figure 2). The open method involved a 2-cm incision through which the MPFL was incised down 1 cm medial to the patellar border. This allowed the placement of 2 imbrication sutures (No. 1 Vicryl), in a pants-over-vest fashion with a modified Mayo

**TABLE 2**  
Concomitant Procedures<sup>a</sup>

Concomitant Procedure	MPFL Procedure, n (%)	
	Reconstruction (n = 256 Knees)	Imbrication (n = 86 Knees)
Simple procedure	9 (3.5)	4 (4.7)
Structural change to the extensor mechanism	130 (50.8)	26 (30.2)
Isolated lateral release with MPFL	62 (24.2)	23 (26.7)
Total	139 (54.4)	30 (34.9)

<sup>a</sup>MPFL, medial patellofemoral ligament.



**Figure 2.** Open medial patellofemoral ligament imbrication technique with pants-over-vest method and secured with modified Mayo stitches.

stitch, while leaving the joint capsule intact. Each procedure was adjusted for the tissue quality and degree of laxity present. The loose MPFL was appropriately tightened to regain lateral stability of the patella, comparable with the contralateral limb.

All patients received the same standardized rehabilitation protocol. This phase-based program emphasized early range of motion and muscle activation, hip and core strength, balance, and proprioception. Immediate postoperative rehabilitation included early weightbearing as

tolerated, with crutches used to facilitate a normal gait pattern. A short period of immobilization in a range-of-motion knee brace (up to 48 hours postoperatively) was followed by unrestricted range of motion of the knee. The rehabilitation protocol progressed to emphasize quadriceps activation, including the use of electrical muscle stimulation, functional exercises, core strengthening, and gait retraining. Return-to-sport training was generally commenced at postoperative 4.5 months.

Patient demographics and predisposing patellofemoral pathoanatomic risk factors were collected at the initial consultation. Demographic risk factors included age at first dislocation, sex, bilaterality of symptoms, body mass index (BMI), affected limb, and previous surgical procedures. Anatomic risk factors included trochlear dysplasia, patella alta, TT-TG distance, generalized ligamentous laxity, lower limb alignment, knee hyperextension, and rotational abnormalities of the tibia and femur. True lateral radiographs were taken at a minimum of 6 months postoperatively to assess the accuracy of the femoral tunnel position following MPFL-R. All patients completed the BPII<sup>16,17,23</sup> preoperatively and at their 1- and 2-year follow-up visits to assess disease-specific quality of life.<sup>20</sup>

Trochlear dysplasia was determined with true lateral radiographs and axial imaging. It was categorized as either low grade (Dejour type A) or high grade (Dejour type B, C, or D). Patella alta was measured with the Caton-Deschamps ratio.<sup>5</sup> The TT-TG was measured as the distance between the tibial tubercle and the deepest part of the trochlear groove on axial imaging according to the method described by Dejour.<sup>4,7</sup> Patellar tilt was measured on axial imaging as the angle formed between the posterior femoral condylar line of the femur and the transverse axis of the patella.<sup>33</sup> Generalized ligamentous laxity, as determined with the Beighton score, was collected for each patient and recorded as a value out of 9.<sup>2</sup> The presence of knee hyperextension was recorded when it exceeded 10° of recurvatum as measured with a goniometer. Femoral anteversion was considered positive on clinical examination if there was internal rotation of the hip >70° and 30° greater than external rotation as measured in the supine position with the hip and knee bent to 90° to relax the muscles and avoid tilt and rotation of the pelvis.<sup>44</sup> Tibial external rotation was considered positive if the thigh-transmalleolar angle was >45° of external rotation as measured in the prone position.<sup>39</sup>

MPFL-R femoral tunnel position accuracy was determined on postoperative true lateral radiographs, taken at a minimum of 6 months postoperatively, by measuring the distance between the center of the femoral tunnel insertion and the center of the Schöttle point.<sup>27,36</sup> A single experienced patellofemoral surgeon (L.A.H.) performed all radiographic measurements at a time independent from the patient encounter. Interrater reliability of this measurement technique has been previously established.<sup>15,19</sup>

### Statistical Analysis

The MPFL-R and MPFL-I cases were analyzed as 2 cohorts. Cases with successful surgical stabilization and those with

a postoperative redislocation were separated within their cohort for comparative analysis. Redislocation rates were calculated by a simple percentage relative to the total number of knees included in the study group.

A Mann-Whitney *U* test was employed to compare the postoperative BPII scores of patients with successful patellofemoral stabilization relative to the prefailure BPII scores of patients who experienced redislocation. This analysis was completed separately for the MPFL-R and MPFL-I cohorts.

Demographic and pathoanatomic data were assessed descriptively for successful MPFL-R and MPFL-I surgical stabilizations as compared with failed surgical stabilizations. Demographic and pathoanatomic data were also analyzed with a Mann-Whitney *U* test (continuous variables) or Fisher exact test (binary variables) to assess for differences between knees with successful surgical stabilization and knees that sustained postoperative dislocation, for both soft tissue surgical techniques. Accuracy of MPFL-R femoral tunnel position was defined a priori as ideal (0-6 mm), good (>6-12 mm), or poor (>12 mm) in terms of distance from the Schöttle point, to assess for any evidence of an association between technical error and surgical failure.

A priori 95% CIs were set as the minimum level of significance. The 95% CIs were calculated for any statistically significant correlation. Statistical analyses were completed with SPSS (v 24.0, IBM).

## RESULTS

### Postoperative Redislocation Rate

In the MPFL-R cohort, 13 knees suffered a postoperative dislocation, resulting in a failure rate of 5.1%. In the MPFL-I cohort, there were 18 knees that suffered a postoperative dislocation for a failure rate of 20.9%. In the MPFL-R redislocation group, 4 knees had undergone a previous MPFL-I, and 1 knee had a previous TTO. Concomitant surgical procedures in the MPFL-R redislocation group included 2 cases of TTO and 1 repair of a previous lateral release. In the MPFL-I redislocation group, none of the knees that sustained a redislocation had previous stabilization surgery. Concomitant surgical procedures in this group included 3 TTOs and 1 repair of a previous lateral release.

### BPII Scores and Postoperative Redislocation

Comparison of postoperative BPII scores for MPFL-R cases with successful patellofemoral stabilization with the prefailure BPII scores of those patients who had a postoperative redislocation revealed a statistically significant difference ( $P = .048$ ). The effect size was 0.16 and was thus classified as small. Comparison of the postoperative BPII scores for MPFL-I cases with successful patellofemoral stabilization with the prefailure BPII scores of those patients with postoperative redislocation also revealed a statistically significant difference ( $P = .003$ ). The effect size was 0.25 and was thus classified as between small and medium. Comparison of the postoperative prefailure BPII scores of

TABLE 3  
Demographic Comparison of the MPFL Reconstruction and Imbrication Cohorts<sup>a</sup>

	MPFL Reconstruction			MPFL Imbrication		
	Total	Intact	Failure	Total	Intact	Failure
Size of cohort	256 knees	243 (94.9)	13 (5.1)	86 knees	68 (79.1)	18 (20.9)
Age, y						
At first dislocation	14.7 ± 4.7	14.7 ± 4.7	13.8 ± 4.3	16.4 ± 6.3	17.1 ± 6.8	13.7 ± 2.8
At time of surgery	24.7 ± 8.7	25.0 ± 8.7	19.2 ± 5.8	23.6 ± 8.8	25.1 ± 9.0	17.9 ± 4.7
BMI, kg/m <sup>2</sup>	23.9 ± 3.8	24.0 ± 3.8	23.3 ± 3.6	23.7 ± 3.4	23.8 ± 3.1	23.2 ± 4.5
Knee						
Left	155 (60.6)	145 (59.7)	10 (76.9)	45 (52.3)	36 (52.9)	9 (50.0)
Right	101 (39.5)	98 (40.3)	3 (23.1)	41 (47.7)	32 (47.1)	9 (50.0)
Bilateral instability	112 (44.1)	105 (43.6)	7 (53.9)	21 (24.4)	15 (22.1)	6 (33.3)
Sex						
Female	184 (71.9)	172 (70.8)	12 (92.3)	73 (84.9)	58 (85.3)	15 (83.3)
Male	72 (28.1)	71 (29.2)	1 (7.7)	13 (15.1)	10 (14.7)	3 (16.7)

<sup>a</sup>Values are presented as n (%) or mean ± SD. BMI, body mass index; MPFL, medial patellofemoral ligament.

the MPFL-R cases (n = 13) with the MPFL-I cases (n = 18) revealed no significant differences between these postoperative redislocation groups ( $P = .91$ )

#### Demographic Risk Factors and Postoperative Redislocation

Demographic comparison of the entire cohort separated by procedure is presented in Table 3. The Mann-Whitney  $U$  test revealed a statistically significant difference for age at the time of surgery between the knees with a successful stabilization and the surgical failure knees (MPFL-R,  $P = .02$ ; MPFL-I,  $P = .04$ ). For the MPFL-R group, the mean age at the time of surgery was  $25.0 \pm 8.7$  years for knees with a successful stabilization and  $19.2 \pm 5.8$  years for the postoperative redislocations. For the MPFL-I group, the mean age at the time of surgery was  $25.1 \pm 9.0$  years for knees with a successful stabilization and  $17.9 \pm 4.7$  years for the surgical failures (Table 3). There was no statistically significant difference between groups for age at the time of the first dislocation, sex, or BMI for either MPFL-R or MPFL-I.

#### Pathoanatomic Risk Factors and Postoperative Redislocation

Descriptive preoperative pathoanatomic risk factors for the MPFL-R cohort are detailed in Table 4. Comparison of the pathoanatomic risk factors between the knees with a successful patellofemoral stabilization including an MPFL-R and those with a postoperative redislocation demonstrated no statistically significant differences between the groups. Femoral tunnel position was assessed relative to the Schöttle point for the MPFL-R cohort. In the intact stabilization cohort, the femoral tunnel was placed a mean  $5.6 \pm 4.1$  mm from the center of the Schöttle point. Eighteen tunnels (6.6%) were rated as poor owing to a measurement  $>12$  mm from the center of the Schöttle point. The positions of the remainder of the femoral tunnels were rated as good or ideal. In the MPFL-R failure group, the mean distance

from the femoral tunnel to the Schöttle point was  $5.3 \pm 2.8$  mm, with all the femoral tunnels rated as good or ideal.<sup>15,19</sup>

Descriptive preoperative pathoanatomic risk factors for the MPFL-I cohort are detailed in Table 5. In keeping with surgical selection, the knees that underwent patellofemoral stabilization with an imbrication demonstrated fewer pathoanatomic risk factors when compared with the cohort that underwent stabilization with a reconstruction. Comparison of the pathoanatomic risk factors between the knees with a successful patellofemoral stabilization including an MPFL-I and those that had a postoperative dislocation demonstrated no statistically significant differences between the groups.

#### DISCUSSION

Using postoperative recurrent dislocation as the definition of failure, this study determined a failure rate for patellofemoral stabilization of 5.1% when an MPFL-R was used as the soft tissue stabilization procedure and 20.1% when an MPFL-I was the stabilizing procedure, at a mean 24.3 months postoperatively. These findings are similar to those reported in systematic reviews.<sup>34,37,40,42,43</sup> The current research adds to the literature regarding outcomes and failure expectations following patellofemoral stabilization surgery, within a large sample of patients undergoing surgery for recurrent patellofemoral instability.

Analysis of the disease-specific quality-of-life scores revealed a significant difference between the successful stabilization and surgical failure groups, with lower mean BPII scores recorded in the cohort of cases that proceeded to surgical failure. The effect sizes of the BPII score differences were calculated as small to medium, and the evidence of this between-group difference merits further study. Further analysis of the predictive validity of the BPII score will be important to explore, but there were insufficient cases to calculate the likelihood of failure on an individual basis.

The risk factors of the successful reconstruction and imbrication stabilization procedures as compared with the

TABLE 4  
Pathoanatomic Risk Factors of the MPFL Reconstruction Cohort<sup>a</sup>

Risk Factor	MPFL Reconstruction, % or Mean ± SD (Range)		P Value
	Intact (n = 243 Knees)	Failure (n = 13 Knees)	
High-grade trochlear dysplasia	52.7	61.5	.62
TT-TG distance, mm	16.6 ± 5.3 (5.0-31.0)	15.2 ± 3.3 (9.6-20)	.45
Patella alta, Caton-Deschamps ratio	1.06 ± 0.13 (0.74-1.53)	1.11 ± 0.13 (0.92-1.35)	.29
Patellar tilt, deg	22.9 ± 12.6 (3.8-58.3)	27.9 ± 4.3 (19.2-31.9)	.31
Femoral anteversion	21.8	30.8	.48
Beighton score	3.8 ± 2.8 (0-9)	4.5 ± 3.3	.37
Cases with score ≥4	50.9	61.5	—
Knee hyperextension >10°	38.6	46.2	.71

<sup>a</sup>MPFL, medial patellofemoral ligament; TT-TG, tibial tubercle–trochlear groove.

TABLE 5  
Pathoanatomic Risk Factors of the MPFL Imbrication Cohort<sup>a</sup>

Risk Factor	MPFL Imbrication, % or Mean ± SD (Range)		P Value
	Intact (n = 68 Knees)	Failure (n = 18 Knees)	
High-grade trochlear dysplasia	31.8	38.9	.58
TT-TG distance, mm	13.3 ± 3.9 (8.2-21.1)	14.1 ± 6.0 (2.3-24.1)	.59
Patella alta, Caton-Deschamps ratio	1.07 ± 0.15 (0.78-1.46)	1.10 ± 0.17 (0.74-1.50)	.35
Patellar tilt, deg	15.1 ± 9.0 (3.0-37.0)	17.3 ± 10.2 (2.3-36.1)	.39
Femoral anteversion	17.8	12.5	≥.99
Beighton score	3.3 ± 2.4 (0-9)	4.3 ± 3.3 (0-9)	.26
Cases with score ≥4	52.9	55.6	—
Knee hyperextension >10°	40.0	44.4	.79

<sup>a</sup>MPFL, medial patellofemoral ligament; TT-TG, tibial tubercle–trochlear groove.

surgical failures demonstrated statistically significant differences between the groups, with a younger age at the time of surgery for the surgical failures. This result may be reflective of a higher risk of recurrence when patellofemoral instability occurs at a younger age, a finding that is consistent with the literature.<sup>22,24,25</sup> Descriptively, the MPFL-R failure group had a higher percentage of cases with pathoanatomic risk factors, including high-grade dysplasia, patella alta, patellar tilt, femoral anteversion, and positive Beighton scores, but none of these differences reached statistical significance. Similarly, the pathoanatomic risk factors of the MPFL-I cases with a successful stabilization as compared with those with surgical failure demonstrated some descriptive but not statistically significant differences. As a whole and in keeping with the surgical selection criteria, the imbrication cases demonstrated a lower incidence of pathoanatomic risk factors compared with the reconstruction stabilization group.

Patients with patellofemoral instability present with a varying number and degree of predisposing demographic and pathoanatomic features. The à la carte concept for the treatment of patellofemoral instability introduced by the Lyon group recommends that significant predisposing anatomic or biomechanical factors be addressed simultaneously with patellofemoral stabilization surgery.<sup>7</sup> Despite the use of these clinical

guidelines, there remains a lack of substantive evidence to guide surgical decision making for most pathoanatomic features associated with patellofemoral instability. Consequently, the thresholds for addressing these risk factors are unclear. Studies that examine the outcomes of patellofemoral stabilization procedures suffer from the inability to access a truly homogeneous patient population. The surgical correction of significant pathoanatomies with the à la carte concept attempts to improve homogeneity in this complex population by correcting significant anatomic or biomechanical pathologies. In this large study cohort that underwent correction of significant anatomic and biomechanical deviations in conjunction with a soft tissue stabilization, examination of the pathoanatomic and demographic risk factors associated with failure of patellofemoral stabilization procedures has provided further information about risk factors and surgical outcomes.

Several studies have reported that up to 50% of MPFL soft tissue stabilization procedure failures are the result of technical error.<sup>9,29,31,41</sup> In this series of MPFL-R procedures, tunnel position was not a contributing factor to failure, as all of the femoral tunnels in the failure group were classified as ideal or good when compared with the reference standard. Therefore, analysis of causes of failure in this study was solely focused on nontechnical causes.



One of the benefits of including the MPFL-I group in this study and analyzing the anatomic risk factors within the patient cohort was to be able to make clinical recommendations regarding which patients may be suitable for the less invasive imbrication procedure. A 21% failure rate could also be seen as a 79% success rate and is in keeping with other stabilization procedures, such as arthroscopic shoulder stabilization.<sup>12</sup> Given that imbrication is a relatively simple procedure with a quick recovery and does not interfere with further surgical treatment options, improvements in patient selection may make this a more attractive option for the right patient.

In terms of study limitations, this research was intended to be a primarily descriptive study analyzing redislocation rates following patellofemoral stabilization. Further long-term follow-up of the patients in this study will be required, as additional surgical failures are likely to occur in subsequent years. This study cohort represents a complex and symptomatic patient cohort assessed at a tertiary referral center for patellofemoral instability and may not be an accurate reflection of the full spectrum of patients seen with this condition. Given the very low failure rate for the MPFL-R group and the low failure rate of the MPFL-I group, statistical comparison of the pathoanatomic risk factors between the intact surgery and redislocation groups was challenging. Therefore, it was difficult to draw clinically meaningful conclusions regarding the associations between anatomic risk factors and postoperative recurrent dislocation, and further studies will be required to elucidate these relationships. One other limitation was that, given the timing of the publication of the BPII, there were too few preoperative BPII scores to run a comparative analysis between pre- and postoperative scores.

Further to this study and in light of the small sample sizes with failures herein, a case-control design would be beneficial to better establish the impact of pathoanatomic risk factors such as trochlear dysplasia, TT-TG distance, and patella alta on patellofemoral stabilization outcomes, including failure rate.

## CONCLUSION

This study has reported postoperative redislocation rates and the prevalence of demographic and pathoanatomic risk factors in a large cohort of patients with patellofemoral instability who underwent patellofemoral stabilization surgery. Patellofemoral stabilization with either an MPFL-R or MPFL-I concurrent with other necessary concomitant procedures to improve the biomechanics of the patellofemoral joint can provide good clinical results with very low and low rates of redislocation, respectively. Younger age at the time of surgery was associated with surgical failure for both soft tissue stabilization procedures.

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