Predicting Risk of Recurrent Patellar Dislocation

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Abstract

Purpose of Review Lateral patellar dislocation (LPD) is one of the most common injuries of the knee, especially in a young patient. It is multifactorial with several underlying risk factors. The purpose of this review is to present the most recent data concerning risk factors and their predictive value to estimate recurrent LPD risk.

Recent Findings Several demographic risk factors (age, skeletal immaturity, sex, bilaterality), mechanism of injury, and anatomic risk factors (trochlear dysplasia, patella alta, excessive tibial tubercle lateralization, increased patellar tilt) have been recognized. The combination of different risk factors, their relative contribution to instability, weightage of each factor, and multivariate analysis have led to the development of a prediction model and instability scoring system.

Summary If recurrent instability and poor outcomes could be predicted based on these prediction tools, then alternative treatment or early surgical intervention after first-time LPD could be considered. This information can also be used to predict contralateral LPD and failure of surgical treatment. Current prediction tools are mainly based on retrospective studies. In the future, prospective validation of these prognostic factors would be beneficial.

Keywords Patellar dislocation · Patellar instability · Patellar subluxation · Medial patellofemoral ligament (MPFL) · Prediction model · Instability severity score

Introduction

Despite systematic reviews and meta-analyses, the ideal management of first-time lateral patellar dislocation (LPD) is unclear [1]. This is partly due to lack of well-done studies and partly due to the multifactorial nature of LPD. In the absence of higher levels of evidence, conservative treatment for first-time LPD has been the standard recommendation. The outcomes after conservative treatment of first-time LPD can be summarized as follows: one third of patients have done well

with return to previous levels of function, one third have had recurrent instability and have required surgical stabilization, and one third of patients have not had recurrent dislocations but have had persistent symptoms including pain, apprehension, giving way episodes, or inability to return to preinjury level of activity [2]. Another concern in patients with LPD has been the development and progression of patellofemoral arthrosis over time [3].

It would be desirable to predict which patients would do well with conservative treatment after first-time dislocation and which patients would not. Prediction of outcomes after first-time LPD would require an initial assessment of all or major factors that contribute to LPD. Once these risk factors are assessed, an algorithmic approach or a prediction model could help identify the “at-risk” patient subset. This information would help to counsel patients and their families as to the prognosis after first-time LPD. If these at-risk patients were predicted to have a significantly higher (> 50%) risk of recurrent instability or persistent symptoms after first-time dislocation, then surgical treatment could be considered for this subset, right from the outset.

Historically, the major risk factors for LPD were identified so that they could be surgically corrected, and not necessarily for their prognostic value. In a 1994 landmark article from

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Lyon, four risk factors for LPD were identified. These were trochlear dysplasia, patella alta (Caton-Deschamps) index ≥ 1.2 , patellar tilt $\geq 20^\circ$, and tibial tuberosity–trochlear groove (TT-TG) distance ≥ 20 mm [4]. Surgical correction of each of the involved risk factor was recommended for successful patellar stabilization and to prevent future patellofemoral arthrosis. Around the same time (1992), the first report of medial patellofemoral ligament (MPFL) reconstruction was published [5]. Thus, two schools of thought related to LPD risk factors and their surgical management emerged. One school of thought was to surgically correct all underlying major risk factors during patellar stabilization surgery. This “à la carte” approach was customized to each patient based on the presence and the magnitude of risk factors. The other school of thought was a standardized surgical approach (MPFL reconstruction) for all patients, knowingly ignoring some or most of the risk factors [6]. Over a period of time, these two strategies have somewhat merged so that MPFL reconstruction may be combined with correction of one or two major anatomic anomalies. There is low-level evidence to support or compare each treatment philosophy. It is possible that the standardized approach of MPFL reconstruction can compensate for lower magnitude or lower number of risk factors, and it might fail beyond a certain threshold [7]. Though attempts have been made to quantify such threshold magnitude for each individual risk factor, it would be desirable to consider the combination of several risk factors and their relative contribution to LPD. Such knowledge would help, not only to predict recurrence but also to decrease failure rates after surgical treatment.

Lately, attempts have been made to weigh individual risk factors and then analyze the predictive values of different combinations of these factors. Such meaningful information could alter medical decision making. For example: The 5-year risk for recurrent instability after first-time dislocation in the younger age group (< 25 years age) has been estimated to be 27% and the 5-year risk for recurrent instability in the presence of trochlear dysplasia has been estimated to be 23% [8]. In isolation, presence of either risk factor would favor conservative treatment after first-time dislocation. However, when these two factors were combined, the 5-year risk for recurrent instability was estimated to be 60% [8]. Thus, given the increased risk for recurrence, the presence of trochlear dysplasia in the younger age group could be considered a subset that would benefit from early surgical stabilization after first-time dislocation. It should also be noted that the overall risk from presence of multiple risk factors is not a cumulative value of summation of various risk factors, but the risk is rather exponential or magnified.

The purpose of this study is to review the latest literature related to the analysis of various risk factors and more importantly, their combined value in predicting recurrent LPD. A review of all risk factors related to LPD is beyond the scope of this article. For this study, the terms patellar dislocation,

patellar subluxation, and patellar instability are used interchangeably as LPD. The pertinent risk factors for recurrent LPD are categorized into demographic factors, injury mechanism, and anatomic factors.

Demographic Factors

Age and Sex

First-time dislocation at a young age has been consistently recognized as a major risk factor for recurrent LPD in almost all studies. The reason for this finding is not completely understood as the severity of trochlear dysplasia, extent of medial-sided injury, and other dysplastic joint features have not been significantly different across all age groups. Another consideration while evaluating the literature is the fact that many reports are restricted to the pediatric age group; this would obviously skew the data towards a much younger age for primary and recurrent dislocation when compared to reports that include the general population [9–11].

The peak incidence of LPD is in the second decade of life. Females within 10- to 17-year age group had the highest risk for first-time and recurrent LPD [12]. The median age for first-time dislocation group was 16 years compared to the median age of 21 years in the recurrent dislocation group [12]. Balcarek et al. reported a significantly high odds ratio (OR) of 11.2 for recurrence, when the instability started before the age of 16 years (Table 1) [13]. When 18-year cutoff age criterion was used, Christensen et al. reported the OR for recurrence to be 2.4 [14]. Lewallen et al. reported that with each year increase in age, the risk for recurrent dislocation decreased by 8%, and there were no recurrences after the age of 40 years [8].

Due to varying levels of skeletal maturity, there is an increasing interest in evaluation of biologic age of the patient, besides the chronologic age. Skeletal maturity is determined based on the patency of the distal femoral and proximal tibial physis on knee imaging studies. If the physis are open or closing, but not closed, then patient is considered to be skeletally immature. Abbasi et al. reviewed adolescent patients with acute traumatic knee hemarthrosis and reported that in younger population with open physes (chronologic age, 10–14 years), LPD was more common (36%) than ACL injury (22%) [16]. Skeletally immature patients had more than two times the risk of recurrent instability (hazard ratio, 2.2) compared to skeletally mature patients (Table 1) [8]. Similarly, Jaquith and Parikh reported that skeletally immature patients had 43.3% risk of recurrence compared to 21.6% recurrence rate in skeletally mature patients ($p < 0.01$) [9]. Chronologic age or skeletal maturity has been part of predictive analysis for combined risk factors in many studies.

Table 1 Risk factors and their reported odds for recurrent patellar instability

Risk factors	Lewallen 2013 [10] HR	Balcarek 2014 [13] OR	Lewallen 2015 [8] HR	Christensen 2017 [14] OR	Jaquith 2017 [9] OR	Sanders 2017 [15] HR
Younger age	0.9	11.2 (16 years)	1.1	2.4 (18 years)	–	1.3
Skeletal immaturity	1.6	–	2.2	–	2.2	–
Female sex	0.8	–	0.9	1.5	–	1.1
Trochlear dysplasia	2.6	4.2	3.3	18.1	3.6	23.7
Patella alta	1.3 ^a	1.4 ^b	1.6 ^a	10.4 ^b	2.1 ^c	10.6 ^b
TT-TG $\geq$ 20 mm	–	1.5 ^d	–	2.1	–	18.7
Bilateral	–	3.2	–	–	3.1	–

OR odds ratio, HR hazard ratio

^a CD or IS $>$ 1.2

^b CD $>$ 1.2

^c CD $>$ 1.45

^d TT-TG $\geq$ 16 mm

Some studies have reported higher rates for LPD in females compared to males. Fithian et al. reported that the risk for recurrent dislocation was three times greater in female patients who had previous history of LPD [12]. This was attributed to increased malalignment and hyperlaxity in females. Nikku et al. reported that female patients with open physes and bilateral instability had the highest risk for recurrent LPD [17]. Christiansen et al. reported an OR of 1.5 for recurrent instability for female patients, compared to males [14]. However, many recent studies have failed to identify any significant differences in the instability rates between sexes (Table 1) [9, 10, 13, 18].

Past History and Contralateral Knee

A detailed history, including history of previous LPD in the index (affected) knee, previous instability in the contralateral knee, and family history of LPD, is imperative in the decision-making process.

A past history of LPD has shown to be the strongest predictor for future patellar instability. Forty-nine percent of patients with prior history of patellar instability had recurrence during follow-up compared to 17% of first-time dislocators who had recurrence; patients with a prior history had seven times higher odds of subsequent instability episodes during follow-up than first-time dislocators [12].

The odds for recurrent instability was three times higher in patients with a history of contralateral LPD, compared to those without contralateral knee involvement (Table 1) [9, 13]. The rate of recurrence after first-time LPD was 62.5% if there was a past history of contralateral LPD [9]. Just as the history of contralateral dislocation could predict recurrence in the index knee, similarly, presence of risk factors in the index knee

could predict contralateral LPD. Christensen et al. reported that the presence of trochlear dysplasia and patella alta in the index knee had an OR of 8.7 and 8.9, respectively, for instability in the contralateral knee [14]. The odds of sustaining contralateral instability were six times higher for patients with recurrent instability of the index knee compared to those without recurrence [12]. In addition, patients with a family history of patellofemoral problems (OR = 3.7) and those who reported factors associated with developmental dysplasia of hip at the time of birth or delivery by cesarean section (OR = 15) had higher odds of contralateral instability [12]. Due to their strong predictive value, history of contralateral LPD, i.e., bilateral LPD, has been included in prediction models.

Mechanism of Injury

The magnitude of trauma at the time of first LPD is an important factor to predict recurrent dislocation. About 50–60% of first-time LPDs have been related to sports [12, 18, 19]. The highest injury rates have been noted in girls' gymnastics (6.19 per 100,000 athlete exposures), boys' football (4.10), and boys' wrestling (3.45) [20]. In another study, basketball was most commonly associated with LPD, accounting for 11.8% of all episodes of LPD and 18.2% of those sustained during athletic activity [18]. Nine percent of first-time dislocations were related to dancing [12]. It has been reported that patients involved in sports activities at the time of the initial dislocation are at significant higher risk for recurrence compared to patients who were not involved in sports (hazard ratio, 1.97), probably related to their return to high-risk activities. The 5-year recurrence-free estimate for sports-related dislocation was 53%, compared to 76% for those not related to sports [8].

In the presence of significant trauma, like a contact injury during sports (valgus and external rotation of leg) or direct blow to the medial aspect of patella, the underlying anatomy of the patellofemoral joint is usually normal. Such high-risk pivoting activities (basketball, football, soccer) were more common in men [21]. On the other hand, LPD after trivial trauma, like low-risk pivoting activities (hiking, jogging, dancing) or no-risk pivoting activities (swimming, cycling), are more common in females [21]. These injuries are likely related to the presence of underlying anatomic anomalies (patellofemoral dysplasia) or joint hyperlaxity. These findings were confirmed by Fithian et al., who found a negative trend between the rate of recurrent instability and the extent of medial-sided injury to the VMO or MPFL. Patients who had recurrent instability had lower (23%) rates of femoral-sided MPFL injury compared to patients who had no recurrence (43% femoral-sided MPFL injury) [12]. In contrast to these findings, Sillanpaa et al. reported that MRI evidence of femoral avulsion of MPFL after first-time dislocation in men could predict recurrent instability (52% recurrence) and inferior outcomes with conservative treatment, compared to patients with midsubstance (9%) or patellar sided MPFL tear (17%) [22]. Thus, patients with femoral avulsion of MPFL after first dislocation could be considered for surgical treatment.

Anatomic Factors

Several anatomic risk factors for first-time and recurrent LPD have been described (Table 2). The qualitative nature of assessment (trochlear dysplasia) and varied measurement methods with different cutoff values have made it difficult to

interpret these factors. We shall focus on the first four major risk factors since they carry more weightage and have been part of prediction tools for recurrent instability.

Trochlear Dysplasia

Trochlear dysplasia is a major factor that is consistently identified in patients with LPD and has one of the highest individual predictive values for recurrent instability and failure of surgery. At least one of the three qualitative signs on a perfect lateral knee radiograph (crossing sign, trochlear bump > 3 mm, and double contour sign) has been identified even in pediatric patients with confirmed trochlear dysplasia [4, 23]. MRI parameters can quantify trochlear dysplasia by measurement of trochlear depth, trochlear facet asymmetry, sulcus angle, and trochlear bump. Dejour classification has been widely used to grade the severity of trochlear dysplasia (grade A to D) but due to decreased interobserver reliability, efforts have been made to group trochlear dysplasia as mild (grade A) or severe (grade B–D) [24, 25]. Besides the shape and depth of trochlea, the length of trochlea is equally important. A dysplastic trochlea cannot offer the bony constraints that are required to stabilize the patella as the knee starts to flex, leading to instability.

Dejour et al. reported that trochlear dysplasia was present in 96% of patients with symptomatic instability compared to 3% in controls [4]. Steensen et al. reported dysplasia in 69% patients with recurrent instability compared to 6% in controls [26]. In recent studies, trochlear dysplasia increased the odds for recurrent LPD after first-time dislocation by 2.6 to 23.7 times compared to patients without recurrence (Table 1).

Patella Alta

Patella Alta, or increased patellar height, has long been recognized as a risk factor for LPD [4]. It would take higher degrees of knee flexion to engage a high-riding patella in to the trochlear groove, thus increasing the likelihood of LPD in early ranges of knee motion. The common techniques for measurement of patella alta are the Insall-Salvati (IS) and Caton-Deschamps (CD) indices on lateral radiographs. Various cutoff values (> 1.2–1.5) have been reported to define what constitutes pathologic patellar height [27]. Patellar height measurements are typically greater in pediatric patients and should be taken into consideration when cutoff values are determined. Knee flexion angle, quadriceps contraction or relaxation, and patellar tendon length can affect these measurements. Attempts have been made to quantify the articular contact and patellofemoral engagement on MRI in order to make the measurement more meaningful. Consensus is lacking as to what is the best method to define abnormal patellar height [27]. The odds of recurrent instability due to patella alta range from 1.4 to 10.6 in the reported literature (Table 1). However,

Table 2 Cited anatomic risk factors for LPD

Trochlear dysplasia
Patella alta
Increased TT-TG distance
Patellar tilt
Increased Q angle
Genu valgum
Patellar morphology
MPFL insufficiency
Vastus medialis muscle hypoplasia
Ligament hyperlaxity
Lateral retinacular contracture
Increased femoral anteversion
External tibial torsion
Subtalar joint pronation
Abnormal Gait
“Core” instability

patella alta has been shown to be present in 36% of controls in one study [28]. Thus, rather than an independent risk factor, patella alta has more value as a risk factor when combined with other factors, like trochlear dysplasia and increased TT-TG distance.

Increased TT-TG Distance

The TT-TG distance has been an indirect measurement of tibial tuberosity lateralization. It is measured on axial CT or MRI images and is a more objective measurement compared to the Q-angle [29]. In one study, the mean distance in the LPD group was significantly increased at 19.8 ± 1.6 mm compared to 12.7 ± 3.4 mm in the control group [4]. Fifty-six percent of patients had more than 20-mm distance compared to only 3.5% in controls [4]. Thus, 15 to 20 mm values have been used as threshold values. However, knee flexion angles, knee rotation, and presence of trochlear dysplasia can influence the measurement. An alternative measurement, TT-PCL (tibial tuberosity–posterior cruciate ligament) distance, has been described [30]. Since absolute values for these measurements do not take into account the size of the knee or the patient, ratios have been suggested [31]. In a recent study, increased TT-TG distance as a single risk factor was never present in the LPD group, i.e., it is more commonly present in combination with other risk factors like patella alta or trochlear dysplasia [28].

Patellar Tilt

Patellar tilt is typically measured on CT or MRI axial images with knee in extension. When measured with the knee in flexion (as in axial radiographs), spurious results can be obtained. In one study, the mean value in the LPD group was $28.8 \pm 10.5^\circ$ compared to $10 \pm 5.8^\circ$ in the control group, which was a significant difference [4]. Eighty-three percent of patients had more than 20° compared to only 3% in controls [4]. The tilt is likely due to medial laxity, lateral retinacular tightness, patella alta, trochlear dysplasia, or a combination of factors.

Combination of Risk Factors for Recurrent LPD

Using a computational finite element model, Fitzpatrick et al. quantified the contribution of 4 key factors to patellar constraint and determined that multiple factors were generally required to produce extremes of patellar alignment [32]. The sulcus angle (trochlear dysplasia) contributed the most (36%) to patellar constraint, followed by patellar height (26%), TT-TG distance (26%), and femoral anteversion (12%). When weighting of each factor was applied (sulcus angle = 1, patella alta = 0.87, TT-TG = 0.89, femoral anteversion = 0.14) in “the

risk of dislocation” algorithm and when anatomic risk factors were measured in patients, 60 patients with recurrent LPD were correctly classified with an accuracy of 90%, while 120 control subjects were correctly classified as normal with an accuracy of 87.5% [32]. This validated the findings by Steensen et al. that about 60% of recurrent dislocators had two or more risk factors compared to 1.7% controls [26].

Based on MRI analysis of 186 patients with LPD and 186 age- and gender-matched controls, Kohlitz et al. reported that trochlear dysplasia was present in 66%, of whom 36% also had patella alta and 9% had increased TT-TG distance [33]. As isolated risk factors, patella alta (15%) and increased TT-TG (1%) were rare. Trochlear dysplasia with abnormal TT-TG was associated with a 37-fold increased risk for LPD and trochlear dysplasia with patella alta was associated with 41-fold increased risk. There were no differences between first-time and recurrent patellar dislocators in this study.

In a pediatric population, Askenberger et al. reported that 79% patients with LPD had two to four risk factors compared to 7% in controls [28]. Trochlear dysplasia with patellar tilt had the strongest association with LPD. The most common factor seen in the control pediatric population was increased patellar height (30%). Lewallen et al. reported that skeletally immature patients (open or closing physes) with trochlear dysplasia had only a 31% success rate with nonoperative treatment after first-time LPD [10]. Thirty-three of 48 patients (69%) had recurrence. The estimates for 1-, 3-, and 5-year survival free of recurrence were dismal at 61, 38%, and 28%, respectively; hence, early surgical intervention may benefit these patients.

Hiemstra et al. profiled their patients into either WARPS or STAIID category, with some having mixed characteristics [34]. WARPS meant Weak, Atraumatic, Risky Anatomy, Pain and Subluxation; STAIID meant Strong, Traumatic, Anatomy Normal, Instability and Dislocation. When demographic and anatomic risk factors were stratified based on these subsets, the WARPS group had greater number of females, earlier age at first dislocation, more bilaterality, higher Beighton score for hyperlaxity, greater percentage of high-grade trochlear dysplasia, a larger TT-TG distance, increased patellar tilt, and increased rotational abnormalities. The STAIID group had more males, later age at first dislocation and more unilateral pathology. There were no differences in BMI, patellar height, activity level, and outcome scores between the two groups. Though each risk factor was not weighted, the constellation of risk factors into two distinct subtypes may have prognostic and therapeutic value.

Time to Recurrent Dislocation

In patients with recurrent LPD, Lewallen et al. reported that about 40% would present within 6 months of their first

episode of dislocation and 62% patients would present in the first year [8]. Similarly, Jaquith and Parikh reported that 61% of patients with recurrence would present in the first year and 97% would present within 3 years of their first dislocation [9]. Based on a study of 232 skeletally immature patients with LPD, of which 104 patients (45%) had recurrence, Sanders et al. calculated the cumulative incidence rate for recurrence [15]. It was 11% at 1 year, 21.1% at 2 years, 37% at 5 years, 45.1% at 10 years, 54% at 15 years, and 54% at 20 years. Thus, nearly half of the patients experienced recurrence and the majority of these recurrences occurred in the first 5 years. The cumulative incidence rates for contralateral instability (18 patients) were as follows: 2% at 1 year, 3.1% at 2 years, 5.2% at 5 years, 7.3% at 10 years, 9.1% at 15 years, and 9.1% at 20 years.

Christensen et al. analyzed the risk factors that would affect the time to recurrent dislocation in a cohort of 173 patients [14]. The mean time to recurrence was 43.9 months. Time to recurrence was significantly decreased in the presence of trochlear dysplasia (by 23 months), increased TT-TG distance (by 18.5 months), patella alta (by 16.4 months), and age less than 18 years (by 15.4 months). Female sex did not affect the time to recurrence. This information may help to determine patients who may benefit from early surgical intervention.

Prediction Model for Recurrent Instability

When multiple risk factors are weighted and the likelihood of recurrent LPD is estimated, then prognosis and alternative treatment options could be incorporated in medical decision making. Lewallen et al. reported that patients younger than 25 years of age with trochlear dysplasia had a 60% risk of recurrence within 5 years of their first episode of dislocation [8]. If patella alta was also present (with young age and trochlear dysplasia), then the risk increased to 70%. For these patients, surgical intervention could be considered after first-time dislocation.

Jaquith and Parikh evaluated multiple risk factors to develop a predictive tool to help estimate the recurrence rate after first-time LPD in patients less than 18 years old [9]. The risk factors were analyzed using patient history and a lateral knee radiograph, and the authors use this model for patient counseling and medical decision making. According to multivariate analysis, risk factors with the highest OR were trochlear dysplasia (3.56 OR), history of contralateral LPD (3.05), skeletal immaturity (2.23), and patella alta (CDI > 1.45) (2.06). Of these four factors, trochlear dysplasia and history of contralateral LPD were weighted heavily, and hence, their inclusion would increase the predicted risk. A simplified prediction model was then developed to make it more applicable in the clinical setting (Table 3). The presence of two or more factors would increase the risk of recurrent instability greater than

50%. In such cases, surgical treatment option could be considered after first-time LPD. In the future, the model could be further strengthened by expanding the age range, inclusion of hyperlaxity assessment and MRI risk factors (TT-TG distance, patellar tilt), and by prospective validation.

Patellar Instability Severity Score

Balcarek et al. proposed the “patellar instability severity score” (ISS) which included six risk factors: age (< 16 years of age), bilateral instability, trochlear dysplasia (none, mild, and severe), patellar height (IS > 1.2), TT-TG distance (> 16 mm), and patellar tilt (> 20°) [13]. The four anatomic risk factors were measured on MRI. Sex and physical activity were not found to be significant factors and hence excluded from the scoring system. Each factor scores one point except severe trochlear dysplasia which scores two points (Table 4). OR for an early episode of patellar redislocation was found to be almost five times higher for patients who scored 4 or more points compared to patients who scored 3 or less points. Thus, surgical intervention could be considered for those with ISS more than 4 points after first-time LPD. The WARPS/STAIID classification system demonstrated strong relationship with ISS, providing further validation of the scoring system [34]. The WARPS subset had mean ISS of 4.4 ± 1.1 (high chances of recurrence) and STAIID subset had ISS of 2.5 ± 1.5 (less chances of recurrence).

Risk Factors for Recurrent Patellar Instability After Surgical Treatment

In a series of 179 patients treated with MPFLR, 38 complications were reported [35]. Complications included recurrent LPD (8 patients), knee motion stiffness (8), patellar fractures (6), and patellofemoral arthrosis and pain (5). Seven of eight patients with recurrent instability had anterior and/or proximal femoral tunnel malposition. Female sex and bilateral MPFLR

Table 3 Prediction model for recurrence after first-time patellar dislocation based on number of risk factors. The four risk factors include trochlear dysplasia, history of contralateral dislocation, skeletal immaturity, and CD > 1.45

Risk Factors	Average predicted risk of recurrence	Treatment recommendation
0	13.8%	Conservative treatment
1	30.1%	Conservative treatment
2	53.6%	Surgery optional
3	74.8%	Surgical treatment
4	88.4%	Surgical treatment

Table 4 Patellar instability severity score. Odds for recurrence are five times higher when total score ≥ 4 points

Risk factors (odds ratio)		Points
Age (11.2)	> 16 years	0
	≤ 16 years	1
Bilateral instability (3.2)	No	0
	Yes	1
Trochlear dysplasia (4.2)	None	0
	Mild	1
	Severe	2
Patellar height (1.4)	≤ 1.2	0
	> 1.2	1
TT-TG (1.5)	< 16 mm	0
	≥ 16 mm	1
Patellar tilt (1.9)	$\leq 20^\circ$	0
	> 20	1
Total score range		0–7

were risk factors for complications and had 5.45 and 1.81 times higher risks for complications, respectively.

Many studies have recognized severe trochlear dysplasia as a major risk factor for recurrent instability after surgical stabilization. In a group of 37 children and adolescents who had recurrent instability and failure of varied stabilization procedures (not MPFLR), Nelitz et al. found the presence of severe trochlear dysplasia on MRI in 89% of patients, compared to 21% in a control population [36]. Patellar height and TT-TG distance were not different between the two groups. Kita et al. reported on 44 knees with MPFLR of which 2 knees had recurrent instability and 8 knees had positive apprehension sign [37]. Severe trochlear dysplasia was the only factor associated with postoperative instability. An increased TT-TG distance (≥ 20 mm) contributed to postoperative instability but only in the presence of high-grade trochlear dysplasia. None of the other factors (age, sex, BMI, patellar type, sulcus angle, patellar tilt, patellar height, TT-TG distance, femoral tunnel position) were found to be significant. Hopper et al. reported a 100% failure rate after MPFLR in the presence of severe (grade C/D) trochlear dysplasia, compared to 9.3% failure rate with mild (grade A/B) trochlear dysplasia [38]. The postoperative outcome scores and patient satisfaction were lower in the presence of severe trochlear dysplasia. The authors recommended against isolated MPFLR in the presence of high-grade trochlear dysplasia. After excluding high-grade dysplasia, recurrent dislocation was significantly associated with trochlear bump height and nonanatomic femoral tunnel placement. Similarly, Hiemstra et al. reported lower postoperative outcome scores in the presence of trochlear bump (≥ 5 mm) and high-grade trochlear dysplasia in a subset of 152 patients

with isolated MPFLR [39]. However, Liu et al. reported on 121 patients with isolated MPFLR and trochlear dysplasia and concluded that in the absence of other risk factors (patella alta, increased TT-TG distance), isolated MPFLR provided acceptable outcomes, including return to sports at minimum 2-year follow-up [7].

Conclusion

The standard approach to conservative management for first-time LPD has been challenged. Recurrent instability rates are higher in younger patients. Patients without recurrent instability after first LPD may still have functional decline and/or arthritis. Thus, a selective approach to management of LPD is recommended. Several demographic and anatomic risk factors have been analyzed, individually and in various combinations. Prediction tools have been developed to anticipate which patients are likely to have recurrence after first LPD; these patients can be offered alternative treatment. These prediction tools have their limitations and could likely be strengthened in future by prospective studies and inclusion of other risk factors.

Compliance with Ethical Standards

Conflict of interest All authors declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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