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Predictors of Recurrent Instability After Acute Patellofemoral Dislocation in Pediatric and Adolescent Patients

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Background: Patellofemoral instability is common in the pediatric and adolescent population, yet prognosis after the first dislocation has been difficult to determine.

Purpose: To describe the demographics of pediatric and adolescent patients with a first-time patellofemoral dislocation and to determine predictors of recurrent instability.

Study Design: Case-control study; Level of evidence, 3.

Methods: A search of the Mayo Medical Index database between 1998 to 2010 was performed, and 2039 patients were identified. Inclusion criteria were (1) age 18 years or younger, (2) no history of patellofemoral subluxation/dislocation of the affected knee, (3) radiographs within 4 weeks of the initial instability episode, and (4) a dislocated patella requiring reduction or convincing history/findings suggestive of acute patellar dislocation (effusion/hemarthrosis, tenderness along medial parapatellar structures, and apprehension with lateral patellar translation). Radiographs were evaluated for trochlear dysplasia (Dejour classification) and patella alta (Caton-Deschamps and Insall-Salvati indices). Skeletal maturity was graded based on the distal femoral and proximal tibial physes (open, closing, or closed).

Results: A total of 222 knees (120 male [54.1%] and 102 female [45.9%]) in 210 patients with an average age of 14.9 years (range, 9-18 years), met the inclusion criteria. Twenty-four patients (10.8%) underwent early surgery. All others were initially treated nonoperatively. Of the 198 patients in this group, 76 (38.4%) had recurrent instability, and 39 (51.3%) of these required surgical treatment. Recurrent instability was associated with trochlear dysplasia ($P < .01$). Patients with both immature physes and trochlear dysplasia had a recurrence rate of 69% (33/48), with a hazard ratio of 3.3. Age, sex, body mass index, and patella alta were not statistically associated with recurrent instability.

Conclusion: Nonoperative treatment for first-time patellofemoral dislocation resulted in a 62% success rate. However, skeletally immature patients with trochlear dysplasia had only a 31% success rate with nonoperative management. Nearly half of patients with recurrent instability required surgical intervention to gain stability.

Keywords: patellofemoral dislocation; pediatrics; adolescents

Patellofemoral instability is a common, often challenging, condition seen in pediatric and adolescent patients.[9,19,20] Several studies have established that 2% to 3% of all knee injuries (adults and children) are due to acute patellar dislocation.[1,10,24] It is one of the most common acute knee injuries in children.[1,10,19-21,24] A Finnish study by Nietosvaara et al[20] reported that the annual incidence of acute patellar dislocation in children younger than 16 years of age was 0.04% (43 per 100,000).

A number of potential risk factors for patellar dislocations have been described in the literature. Anatomic factors include trochlear dysplasia, patella alta, patellar tilt, increased Q angle (due to lateralized tibial tubercle, genu valgum, femoral anteversion, or external tibial torsion), generalized ligamentous laxity, weakness of vastus medialis, and pes planus/subtalar joint pronation.[5,8,24] Female sex, sports participation, and a personal or family history of patellar instability have also been considered risk factors. However, less is known about the differences in pediatric versus adult populations and about why some patients go on to have recurrent instability and others do not. The potential long-term complications of acute patellar dislocations include (anterior knee) pain, decreased activity level, recurrent instability/dislocations, and patellofemoral arthritis.[24]

Nonoperative treatment, with closed reduction and immobilization followed by rehabilitation and strengthening, is the standard of treatment for the majority of

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first-time dislocations.[5,6,15,21] In cases of chronic or recurrent instability that have failed nonoperative management, the surgical plan is often tailored to the individual (based on history, anatomic factors, age, etc). Yet controversy exists regarding the indications and timing for more aggressive management as well as the type of procedure to be performed. This is particularly true in children, because open growth plates present an additional challenge.[14,23]

A systematic review of the literature by Stefancin and Parker[24] concluded that nonoperative management is preferred for acute patellar dislocations, unless there is evidence of "chondral injury, osteochondral fractures or large medial patellar stabilizer defects (MPFL [medial patellofemoral ligament], medial retinaculum, VMO [vastus medialis obliquus])." It is important to note, however, that a number of studies report that up to 44% of patients will go on to have recurrent dislocations[2,4,7,24] and approximately half will have recurrent instability or pain (after nonoperative treatment).[11,24] For these reasons, it would be advantageous to be able to classify patients at the time of initial injury based on their risk for recurrent instability. With the increasing number of options for surgical management of this complex problem, it is important to determine which patients may benefit from earlier surgical intervention and which are better suited for nonoperative management.

The purpose of this study was to describe the demographics of pediatric and adolescent patients (age $\leq$18 years) sustaining a first-time patellofemoral dislocation and to identify predictors of recurrent instability. This information may be used to assist in assessment of risk of recurrent instability and thereby help guide treatment in the clinical setting.

MATERIALS AND METHODS

This was a single-institution, retrospective review of patients with acute patellofemoral dislocation between January 1, 1998, and December 31, 2010. The study was approved by the institutional review board. A search of the Mayo Medical Index database for keywords "patellofemoral subluxation/dislocation/instability" or "displaced patella" generated a list of 2039 patients. Clinical records were reviewed and selected for inclusion based on the following criteria:

1. Age 18 years or younger at the time of injury.
2. No history of patellofemoral subluxation/dislocation of the affected knee.
3. Radiographs within 4 weeks of the initial instability episode.
4. A dislocated patella requiring reduction, a diagnosis of patellofemoral dislocation, or convincing history/findings suggestive of acute patellar dislocation (a subluxation or dislocation event associated with full giving away, effusion/hemarthrosis, tenderness along the medial parapatellar structures, and apprehension with lateral patellar translation).[3,10,18]

Reasons for exclusion were associated major ligamentous injury (anterior cruciate ligament, posterior cruciate ligament, or lateral collateral ligament) or knee dislocation, chronic/recurrent instability at the time of presentation or previous patellofemoral disorder, lack of appropriate imaging, no clear history of acute patellofemoral dislocation, and no research authorization.

Therefore, of the initial 2039 patients, 222 knees (210 patients) with adequate clinical documentation and imaging met inclusion criteria for this study. Data abstracted from the charts included age at time of injury, sex, mechanism of injury (sport related vs non–sport related), height/weight/body mass index (BMI), required reduction (yes/no, and if so reduced by emergency department physician/self/other), date of radiographs, type of treatment, date/type of operation if performed, date of any recurrent instability events (including repeat dislocation or ongoing subluxation symptoms),[22] treatment for recurrence, and date/type of operation if performed.

Radiographic Measurements

Radiographs performed within 4 weeks of the initial injury were obtained and analyzed by A.L.M. and D.L.D., who were blinded to the clinical history. The presence of trochlear dysplasia was determined using the Dejour classification system (Figure 1). Satisfactory lateral radiographs were available in the majority of cases. When a question arose regarding the presence or absence of trochlear dysplasia due to a "less-than-perfect" lateral radiograph, a decision was made by consensus of both senior authors using both lateral and axial imaging. Severity was graded based on the presence of the following: crossing sign, supratrochlear spur, and/or double contour sign.[4,8] Trochlear dysplasia was recorded as present or not, and any Dejour grade (A-D) was considered trochlear dysplasia.

Lateral radiographs were also assessed for patella alta using the Caton-Deschamps index and the Insall-Salvati index (Figure 2).[9,25] If the patient met the criteria for patella alta based on either index (ratio $>$1.2), then he or she was considered to have patella alta (ie, did not require both). Measurements were made on the QREADS system for electronic images and by hand for those images available only on hard copy film.

Skeletal maturity was graded based on the distal femoral and proximal tibial physes. The following categories were used: open, closing, or closed. We considered those subjects with open or closing physes to be skeletally immature and those with closed physes to be skeletally mature.

Statistical Methods

Statistical analysis was performed by a certified statistician. Descriptive statistics are reported as number (percentage). Recurrence-free survival was estimated with the Kaplan-Meier method. The association of patient characteristics with the risk of recurrence was assessed with Cox proportional hazards regression, accounting for the 12 patients with bilateral knee involvement. The α level was set at .05 for statistical significance.

Figure 1. Trochlear dysplasia. 1 = crossing sign; 2 = supratrochlear spur; 3 = double contour.

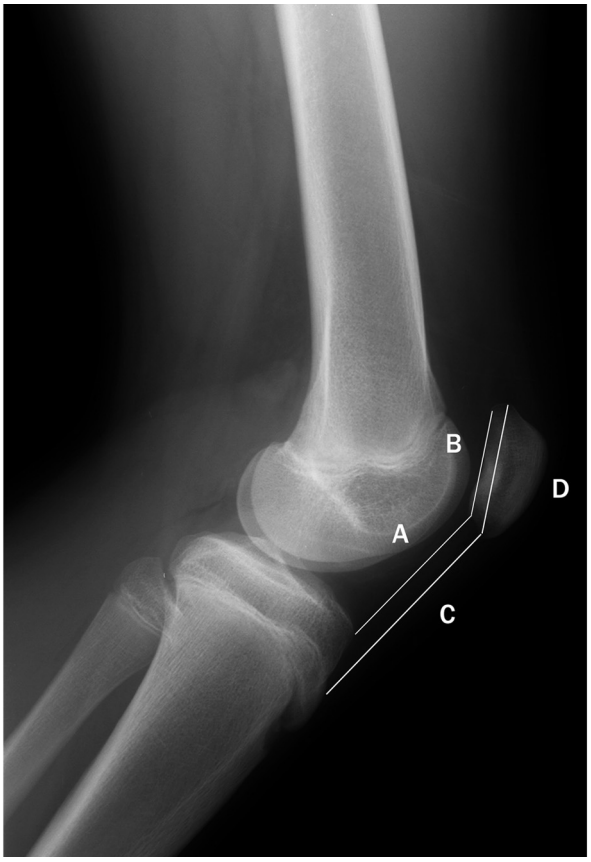

Figure 2. Patella alta. Caton-Deschamps index = A/B; Insall-Salvati index = C/D.

RESULTS

Data are reported based on the total number of knees rather than the number of subjects. A total of 222 knees (210 patients) were included in this study. There were 102 females (45.9%) and 120 males (54.1%), with an average age of 14.9 years (range, 9-18 years). All except 1 of the patients were students. One hundred and fifty-eight patients (71.2%) were involved in sports at the time of the injury. Eighty-four patients (37.8%) had trochlear dysplasia, and 100 patients (45.0%) had patella alta. Forty-one patients (48.8%) with trochlear dysplasia were female, and 43 (51.2%) were male. One hundred and fifteen patients had open (12.6%) or closing (39.2%) physes, and 107 patients (48.2%) had completely closed physes (Table 1).

The mean follow-up time in this series was 3.1 years (range, 3 days to 12.5 years). Of the total 222 knees in the series, 211 (95.0%) were seen in follow-up at some point at our institution. For statistical purposes, follow-up was terminated when a recurrent instability event occurred. Excluding the patients who developed recurrent patellar instability, the median follow-up was 3.43 years; 92 of 122 patients (75%) had a follow-up time of longer than 1 year.

Of the total 222 cases of acute patellar dislocations, 24 (10.8%) underwent early surgery. Three knees had a diagnostic arthroscopy alone. Nine knees were treated with arthroscopy and loose body removal, with or without chondroplasty. One had an osteochondral fragment treated with open reduction internal fixation. The remaining knees were treated with a stabilizing procedure. Ten knees underwent arthroscopy, loose body removal, and open MPFL repair. The final knee underwent arthroscopy, loose body removal, and open lateral release followed by medial imbrication of the extensor mechanism. The mean time from injury to surgery was 29.8 days (range, 3-89 days). Of the 24 cases treated with initial surgery, 8 (33%) had

TABLE 1
Demographics (N = 222 knees in 210 patients)[a]

Sex	
Female	102 (45.9)
Male	120 (54.1)
Age, y, average (range)	14.9 (9-18)
Sports-related injuries	158 (71.2)
Trochlear dysplasia	84 (37.8)
Patella alta	100 (45.0)
Skeletal maturity	
Open physes	28 (12.6)
Closing physes	87 (39.2)
Closed physes	107 (48.2)

[a]Data are expressed as n (%) unless otherwise indicated.

TABLE 2
Kaplan-Meier Estimates and Associations With Risk of Recurrence[a]

Variable	Total (Event)	2-y Recurrence Rate Estimate, % (95% CI)	5-y Recurrence Rate Estimate, % (95% CI)	Hazard Ratio (95% CI)	*P* Value
Age, per year	198 (76)	—	—	0.920 (0.83-1.01)	.08
Sex					
Male	105 (44)	64 (55-75)	48 (38-60)	1.0 (Ref)	—
Female	93 (32)	68 (59-79)	59 (48-72)	0.800 (0.50-1.26)	.33
BMI					
>25	51 (22)	66 (53-81)	47 (34-66)	1.0 (Ref)	—
≤25	83 (40)	61 (51-73)	47 (36-61)	1.17 (0.69-1.96)	.56
Mechanism of injury					
Non–sport related	59 (17)	76 (65-88)	67 (54-82)	1.0 (Ref)	—
Sport related	138 (58)	62 (54-72)	47 (39-58)	1.69 (0.99-2.87)	.06
Patella alta					
No	108 (38)	70 (61-80)	57 (47-69)	1.0 (Ref)	—
Yes	90 (38)	61 (51-73)	48 (37-62)	1.29 (0.83-2.01)	.25
Skeletal maturity					
Closed	94 (26)	70 (60-81)	66 (55-78)	1.0 (Ref)	—
Open/closing	104 (50)	63 (54-74)	44 (35-57)	1.58 (0.97-2.57)	.06
Trochlear dysplasia					
No	121 (31)	76 (68-85)	67 (57-78)	1.0 (Ref)	—
Yes	77 (45)	52 (41-65)	35 (25-49)	2.57 (1.62-4.08)	<.01

[a]BMI, body mass index; CI, confidence interval; Ref, reference statistic.

recurrent instability, 7 (87.5%) of which later required a second or even third surgery to gain stability.

All other patients were initially treated nonoperatively. Of the 198 cases in this group, 76 (38.4%) went on to have recurrent subluxation or dislocation. Among the 76 instability events during the available follow-up period, 30 (39.5%) had occurred within the first 6 months, 47 (61.8%) within the first year, and 67 (88.2%) within the first 3 years. Thirty-nine (51.3%) of the 76 cases of recurrent instability underwent surgical intervention. The remaining patients chose to continue with nonoperative treatment.

The whole group (N = 222) was assessed for factors associated with recurrent instability. Eight cases of recurrent instability occurred in the early operative group, and 76 occurred in the nonoperative group, for a total of 84 knees with recurrent instability. Recurrent instability was strongly associated with trochlear dysplasia (hazard ratio [HR], 2.57; 95% confidence interval [CI], 1.62-4.08; $P < .01$). Of note, 49 of the 84 knees (58.3%) with recurrent instability showed evidence of trochlear dysplasia.

Sports participation and immature physes demonstrated a borderline increased hazard ratio but were not statistically significant. Age, sex, BMI, and patella alta were not significantly associated with the risk of recurrent instability (Table 2).

A statistical model was examined after patients were categorized into 1 of 4 groups based on physeal status (open/closing vs closed) and presence of trochlear dysplasia (yes vs no) (Table 3). The reference group consisted of patients with closed physes and no trochlear dysplasia. For a patient with open/closing physes and trochlear dysplasia, the risk of recurrent instability was increased by a factor of 3.3 (HR, 3.3; 95% CI, 1.8-6.0; $P < .001$). For a patient with closed physes and trochlear dysplasia, the risk was increased by a factor of 2.2 (HR, 2.2; 95% CI, 0.97-4.9; $P = .06$). Last, for a patient with open/closing physes and no trochlear dysplasia, there was no statistically significant increased risk (HR, 1.2; 95% CI, 0.6-2.5; $P = .54$).

TABLE 3
Analysis of Maximum Likelihood Estimates[a]

	Hazard Ratio (95% CI)	*P* Value
Open/closing physes and trochlear dysplasia	3.3 (1.8-6.0)	<.001
Closed physes and trochlear dysplasia	2.2 (0.97-4.9)	.06
Open/closing physes and no trochlear dysplasia	1.2 (0.6-2.5)	.54
Closed physes and no trochlear dysplasia	1.0 (Ref)	

[a]CI, confidence interval; Ref, reference statistic.

For the nonoperative group overall (n = 198), 76 (38.4%) patients were found to have recurrent instability during the available follow-up period. The Kaplan-Meier estimates for recurrence-free survival at 1, 3, and 5 years were 73%, 59%, and 53%, respectively (Figure 3).

Among patients with immature physes and trochlear dysplasia, 33 (68.8%) of the 48 patients had recurrent instability events identified during the period of observation. For this group, the estimates of survival free of recurrent instability at 1, 3, and 5 years were 61%, 38%, and 28%, respectively (Figure 4). For the reference group, skeletally mature patients with no trochlear dysplasia, the estimates for recurrence-free survival at 1, 3, and 5 years were 85%, 73%, and 73%, respectively (Figure 4).

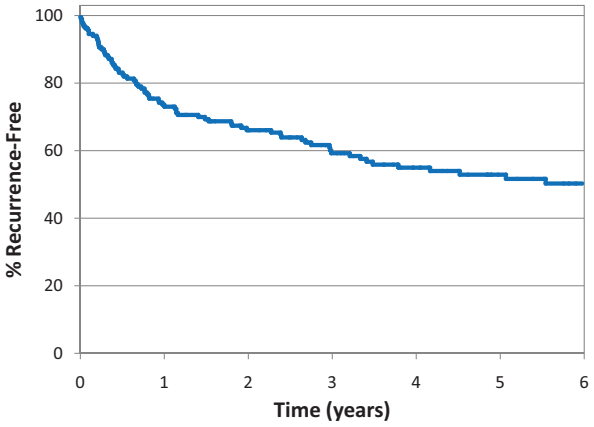

Figure 3. Overall recurrence-free survival.

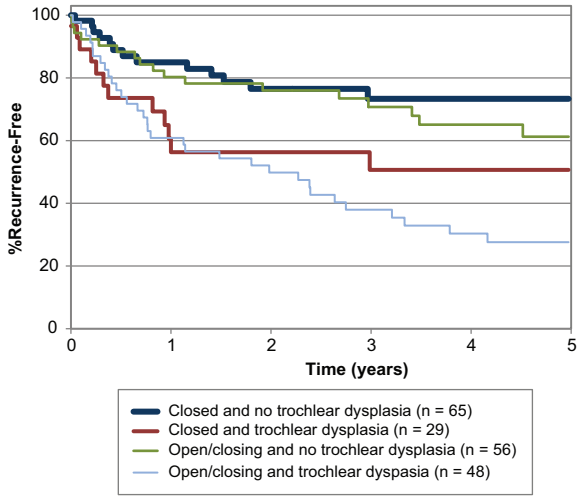

Figure 4. Recurrence-free survival by group.

DISCUSSION

Strengths

The large number of patients is a strength of this study. Most reports on this topic among the pediatric population have included fewer than 100 patients.[1,16,17,20] A larger epidemiologic study was reported by Hsiao et al[13]; however, the patients were 18 years and older and represented a military population.

The assessment of trochlear dysplasia is another strength, because all patients had lateral radiographs available within 4 weeks of injury. These images were evaluated for the presence of a crossing sign, supratrochlear spur, and/or double contour.[9,15] The severity of trochlear dysplasia was then determined.

Finally, the incorporation of skeletal maturity in the radiographic evaluation is also a strength, as this provides information on bone age in addition to chronological age. Given the importance of considering skeletal maturity in preoperative planning, this additional information regarding the relationship between skeletal maturity and recurrent instability is valuable. We believe that this information may influence the timing and type of operation performed.

Limitations

The main limitation of this study is the retrospective nature of the study design. The mean follow-up was 3 years. However, only 75% of patients had greater than 1 year of follow-up. Of the total 222 cases, 11 patients (5%) were seen only at the time of injury. Therefore, the outcomes for these remaining patients are unknown. There may have been more episodes of recurrence of which we are not aware.

Strict criteria were followed for inclusion in this study. However, not all patients had an MRI to radiographically confirm the diagnosis of a lateral patellar dislocation.

Mechanical axis/limb alignment and tibial tubercle to trochlear groove distance could not be routinely obtained because of the retrospective nature of the study. (Standing anteroposterior lower extremity full-length radiographs and axial computed tomography were not performed on the majority of patients.)

Prognostication

First-time patellofemoral dislocation in patients aged 18 years or younger had a nearly equal sex distribution. This differs from previous studies that have shown an increased risk for females.[7,15] Although the classic description of a patient with patellofemoral instability is an adolescent, overweight female, this has been questioned by a number of authors in recent years.[3,6] Our study showed that increased BMI was not associated with an increased risk for recurrent subluxation or dislocation.

Patients involved in sports at the time of the initial dislocation had a borderline increased hazard ratio for recurrent instability ($P = .055$). These patients were nearly 70% more likely to have a recurrence than those not involved in sports (HR, 1.69; 95% CI, 0.99-2.88). Patients with immature physes (open or closing) also demonstrated a borderline increased hazard ratio and were nearly 60% more likely to have a recurrent event than those with mature physes (closed) (HR, 1.58; 95% CI, 0.97-2.57; $P = .06$). Both of the P values trended toward significance and are consistent with previous reports that repeated exposure to the injury mechanism in the skeletally immature patient is a major risk factor for ongoing instability.[3,5] A recent study by Seeley et al[22] showed the highest incidence of recurrence among the youngest patients. This suggests that younger (skeletally immature), more active patients may benefit from earlier surgical intervention.

Approximately 10% of the patients in this series underwent surgery after the initial dislocation event. This is consistent with previously published rates of early surgical intervention.[5,20] The majority of patients with acute patellar dislocation were initially managed nonoperatively. Other studies have reported redislocation rates up to 44% among such patients.[2,4,7,24] In this series, 38% of patients treated nonoperatively went on to have recurrent instability

episodes (either subluxation or dislocation) during the period of observation. Therefore, nonoperative treatment for first-time patellofemoral dislocation resulted in a 62% success rate overall. However, patients with immature physes (open/closing) and trochlear dysplasia had only a 31% success rate with nonoperative management. It is interesting to note that 51% of patients with trochlear dysplasia were male. In this group, recurrent instability events occurred in 62% of patients within 3 years of follow-up. In addition, half of all patients with recurrent instability underwent surgical intervention to gain stability.

With available follow-up in this series, recurrent instability was most likely to occur within the first year of the initial injury. More than 60% occurred within the first year and nearly 90% by 3 years. The information is useful when counseling patients on risk factors and expected time course.

Radiographs

Some authors suggest that radiographic risk factors play a greater role in recurrent instability than acute dislocations.[12] In this series, patients with radiographic evidence of trochlear dysplasia were more than 2.5 times more likely to have recurrent instability. Interestingly, patella alta did not appear to be a risk factor for recurrence in this study. The radiographic criteria used in adults are well established but have not been extensively studied in the pediatric population.

Thévenin-Lemoine et al[25] examined a large cohort of children and found the Caton-Deschamps index to be highly reproducible, although these were children with minor knee trauma (not patellofemoral dislocations) and normal knee radiographs. Therefore, these measurements do not provide information on whether patella alta correlates with risk of acute/recurrent dislocations. The Insall-Salvati index has also been shown to be reproducible in adolescent patients. However, certain authors have concluded that because of the cartilaginous nature of the patella in younger patients, patella alta is not easily measured on standard radiographs.[12,26] Patella alta was not identified as a risk factor for ongoing instability in our study.

A recent report by Lippacher et al[16] evaluated whether trochlear dysplasia based on lateral radiographs are applicable to patients with open growth plates. The investigators looked at 28 patients with recurrent patellar dislocations and MRI diagnosis of trochlear dysplasia and found that these patients also had at least 1 sign of trochlear dysplasia on lateral radiographs (crossing sign, supratrochlear spur, or double contour). The authors concluded that lateral radiographs are sufficient for evaluation of trochlear dysplasia in this population.

In our study, univariate models were assessed with a reference group of "no trochlear dysplasia, and closed physes" (Table 3). This demonstrated a greater than 3-fold increased risk of recurrent instability for patients with immature physes and trochlear dysplasia. Patients with mature physes and trochlear dysplasia had more than double the risk. There was no statistically significant increased risk for patients with immature physes and no evidence of trochlear dysplasia. These findings confirm that the combination of skeletal immaturity and trochlear dysplasia carries the worst prognosis regarding risk of recurrent instability.

CONCLUSION

Nonoperative treatment for first-time patellofemoral dislocation yielded a 62% success rate overall. However, 51% of patients with recurrent instability required surgical intervention to gain stability. In addition, patients with open/closing physes and trochlear dysplasia failed nonoperative treatment 69% of the time and were 3.3 times more likely to have a recurrent instability event. Age, sex, BMI, and patella alta did not appear to be risk factors for recurrence in this cohort.

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