Patellofemoral instability part 1

(When to operate and soft tissue procedures): State of the art

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Abstract

Patellofemoral instability is usually initially treated non-operatively. Surgery is considered in patients with recurrent patellar dislocation, and after a first-time patellar dislocation in the presence of either an associated osteochondral fracture or high risk of recurrence. Stratifying the risk of recurrence includes evaluating risk factors such as age, trochlear dysplasia, contralateral dislocation and patellar height. Surgery with soft tissue procedures include restoring the medial patellar restraints and balancing the lateral side of the joint. Reconstruction of the medial patellofemoral ligament is the most frequent way of addressing the medial soft tissues in patients with patellofemoral instability. Meanwhile, lateral tightness can be achieved by lateral retinaculum lengthening or release. Approaching patellofemoral instability in a patient-specific approach, combined with a shared decision-making process with the patient/family, will guide surgeons to the deliver optimal care for the patellar instability patient.

Introduction

A rapidly expanding body of literature has begun to shed light as to the best management of lateral patellofemoral (PF) instability. This is in part due to
advances in imaging, improved understanding of underlying PF biomechanics as well as improved, quantifiable PF physical examination techniques. All of these have led to an increased focus on proper identification of the contribution of injured structures while appreciating underlying the anatomic, demographic, and social factors that may predispose a patient to a patellar dislocation and secondary risk of re-injury. Current evidence will be reviewed to provide a treatment algorithm that best guides the management of patients with a first-time PF dislocation, recurrent dislocation and when and how specific anatomic structures or mal-alignment issues should be addressed to prevent re-dislocation. (Figure 1)

Operative versus non-operative treatment after the first episode of acute patellar dislocation

First time (primary) lateral patellar dislocations often occur in young skeletally immature adolescents, though they may occur at any age[1–4]. These primary dislocation events are often associated with cartilage disruption[5–8] and carry an increased risk of repeat dislocation.

After an acute first-time patellar dislocation, surgical intervention is recommended under certain circumstances: 1) In the presence of osteochondral fractures or loose bodies requiring internal fixation and/or fragment removal. 2) Patients who are at high risk for redislocation. 3) Patients with persistent functional
patellar instability (e.g. excessive laxity on the physical examination, unable to reach previous activity level or persistent lack of confidence in the knee) after non-operative treatment.

Traditionally, all first time dislocators that did not have a significant chondral/osteochondral injury were initially treated conservatively. Should a patient fail non-operative management and re-dislocate they then underwent surgical stabilization of the patella. However, currently, the treatment algorithm is shifting. Failure of initial non-operative management carries significant morbidity for the patient (recurrent dislocation event, increased risk of patellofemoral chondral damage, and decreased activity)[6,9,10]. Patellar stabilization procedures have been shown to decrease such risks through reducing the rate of re-dislocation[11]. However, even patients who do not report recurrent patellar dislocations are in many cases quite limited by this injury[10].

Delay in operative treatment of patients with patellar instability can be common. Patients with patellar instability have been shown to have knee function affected as much as anterior cruciate ligament (ACL) deficiency, and associated with more pain[12]. Still, patellar instability patients have been shown to wait on average 5 times longer for surgery (6 vs 31 months)[12]. Therefore, in the evaluation of such a patient, a systematic approach should be taken to determine the role and timing of surgical intervention to prevent future dislocation events. Risk assessments, combined with shared decision making with the patient/family is ideal, as it is recognized that many patients can cope with recurrent patellar
dislocations[13]. Similarly, it has been shown that surgical treatment confers greater benefits to an individuals’ athletic and quality of life measures than with activities of daily living[11].

Several recent studies, as reviewed by Schlichte et al[14] and Huntington et al[15], have emerged to better define recurrence risk of a first time dislocator. The primary risk factors of re-dislocation are: younger age[16–20], skeletal immaturity[3,16,18,21], troclear dysplasia[3,16–22], patella alta[3,16–21], increased tibial tubercle(TT)-troclear groove(TG) distance[17,19,20,23], and bilateral patellar dislocations[17,21], while previously described risk factors such as female sex[16,18–20] and medial patellofemoral ligament (MPFL) injury pattern[24] were shown not to be predictive (Table 1). Furthermore, having more than one of these risk factors has been shown to have an additive effect on the overall re-dislocation rate[3,15,16,21,25,26] (Table 2). A patient that has several factors, may have more than 70% risk of re-dislocation.[26] This discussion about treatment may be similar to the common conversation with an adolescent male in a contact sports that is at increased (>75%) risk of recurrence after primary glenohumeral dislocation[27,28].

Researchers from the Mayo clinic (Martin et al)[29] developed a novel scoring system entitled the Recurrent Instability of the Patella (RIP) score. The model was developed from a cohort of operative and non-operatively managed patients with >10-year follow-up. The RIP score considers patient’s age (chronologic age <25 (2 points)), their skeletal maturity (skeletal immaturity (1
point)), presence of trochlear dysplasia (Dejour classification A-D carried (1 point)), and the TT-TG to patellar length (PL) ratio (ratio $\geq 0.5$ (1 point)) [25][15,30], [27,28]. The score presents some intrinsic limitations, the difficulty of establishing a binary cut point for continuous variables, patellar height is not included and the risk due to trochlear dysplasia is not graded by severity of the trochlear dysplasia; thus, the authors recommend that the score is used with caution.

When non-operative management is chosen, patients are allowed to fully weight bear as tolerated, with gradual increases in range of motion and strength[29]. Knee effusions may be therapeutically aspirated in some cases at initial presentation; this can also potentially improve patellar reduction while the soft tissue stabilizers heal. Rigid immobilizations (e.g. posterior splints or plaster casts) are associated with knee stiffness and arthritis[31]. In addition, Kaewkongnok et al, demonstrated that duration of immobilization has no effect of re-dislocation rate[32]. Therefore, brace and crutches should only be used on the acute phase to help decrease swelling and improve gait. A patellar sleeve brace can be used up to 6 weeks. Expected return to sport is between 6 to 12 weeks.

**Surgical treatment**

Surgical treatment is indicated in the vast majority of patients with recurrent patellar dislocation, as the risk of further recurrence is elevated in these cases, in
addition to the risk factors that may have been present at the time of first-time
dislocation, as discussed above.

The ‘a la carte’ approach, developed by Dejour and Walch, as well as the
‘Lyonnaise’ team, offers individualized treatment of each knee based on
anatomic abnormalities identified radiographically that may be contributing to
the instability[33,34]. This approach has since evolved; with the addition of the
reconstruction of the medial soft tissue restraints of the patella[35–37]. This came
from the growing recognition of the importance these medial static stabilizers
have on PF mechanics[38–40].

Restoring the medial patellar restraints

Medial retinaculum repair

If surgery is indicated in the acute setting due to the presence of an
osteochondral fragment[14], MPFL repair can be considered in patients with low
risk of recurrence. However, Pedowitz et al found that children in this setting have
a 61% recurrent instability rate. In particular, patients with a TT-TG distance greater
than 15 mm were at highest risk for recurrent instability. Importantly, they found
that MPFL repair did not decrease the recurrence rate, although there was
heterogeneity in the time to surgery in this series[41]. Askenberger et al, reported
in a level 1 randomized control trial that MPFL repair reduced the redislocation
rate (22%) compared to non-operative treatment (43%), but did not improve subjective or objective knee function\[42\]. In addition, Puzzitiello et al found a nearly 6 times greater recurrent dislocation rate after MPFL repair (36.9%) compared to MPFL reconstruction (6.3%), especially in the setting of an elevated Caton Deschamps index (CD)\[43\]. Nearly all of the knees that underwent MPFL reconstruction had multiple prior dislocations (96.9%), while roughly over half (63%) of the knees that underwent MPFL repair had multiple dislocations, strengthening the argument of reconstruction over repair in recurrent patellar instability\[43\]. Similar studies have shown high rates of recurrent dislocation with repair (28\%\[44\] and 46\%\[45\]). Thus, the authors prefer MPFL reconstruction in such cases. Given the acute nature of injury, concern for possible stiffness should be anticipated, thus consideration for a staged MPFL reconstruction can be made.

Ligament reconstruction: MPFL, MQTFL and MPTL

The medial patellofemoral complex (MPFC) can be broken down into the proximal restraints [the medial quadriceps tendon femoral ligament (MQTFL) & MPFL] and the distal restraints [the medial patellotibial ligament (MPTL) and the medial patellomeniscal ligament (MPML)]\[46,47\]\[Figure 2 & 3\]. The work horse of these medial structures is the MPFL\[47–51\]. As such, the MPFL reconstruction has become the foundational surgical stabilization procedure for lateral patellar instability\[1,52–55\].
MPFL reconstruction has demonstrated good short-term success with low recurrence rates (6.3%) \cite{43,53,55,56} but does carry its own complications. One systematic review reported a rate of 26.1\%, ranging from minor to major events\cite{57}. Broad classifications of failures included patellar fracture, returning to the operating room to correct residual instability, findings of clinical instability on postoperative examination, loss of knee flexion, wound complications, and pain.

To avoid the catastrophic complication of patella fracture due to patellar drilling, Noyes and Albright have described an MPFL reconstruction technique utilizing autologous quadriceps tendon while keeping the patellar attachment intact\cite{58}, and Fulkerson and Edgar described the MQTFL reconstruction, which employs fixation to the quadriceps tendon instead of the patella\cite{37,40,59,60}. It is important to notice that even though high rates of patellar fracture (2.5\%)\cite{61} from transosseous tunneling through the patella have been described, a systematic review found only a 0.5\% (3/629 patients) rate of patellar fracture, associated with patellar tunnels\cite{57}. In addition, a biomechanical study showed that that risk of fracture is increased when the anterior cortex is violated\cite{62}. Therefore, patellar fracture is not a main concern with other patellar fixations, such as anchors. However, it is important to notice that some anchor designs require the drilling of 18-20mm length tunnels potentially increasing the risk of fracture.

The MQTFL reconstruction has been shown to restore native stability without increasing contact pressure\cite{63} and to be effective in short term clinical outcomes\cite{59,64}. One should beware that the MPFC demonstrates the most
significant length changes between 0° and 20° of flexion, while more isometric behavior was seen during 20°–90°. The attachment points along the extensor mechanism demonstrate different length behaviors, where the more proximal components of the MPFC display greater anisometry through the arc of motion[65]. Anisometry of the MPFC varies not only with attachment location on the extensor mechanism but also with patellar height. Increased patellar height leads to more significant changes in anisometry in the proximal MPFC attachment point as compared with the distal component[66]. Therefore, when performing a proximal MQTFL reconstructions, surgeons should expect increased length changes compared to reconstructions utilizing distal patellar attachment sites, especially in the context of patella alta. Furthermore, many authors have begun to reconstruct both the MPFL & MQTFL ligaments simultaneously, coined the proximal medial patellofemoral complex (MPFC) reconstruction[46,67,68]. The growth of the proximal MPFC reconstruction can be attributed to a better appreciation of the discrete yet closely related functions of each medial patellar soft tissue restraint[67,69–71]. Spang et al. has reported on a single surgeon cohort (n=25) performing a combined reconstruction with two-year follow-up. Their study has demonstrated a favorable safety profile and re-dislocation rate as compared to previously published medial retinacular plication[72] and isolated MPFL reconstruction[73].

Descending distally from the MPFC, growing evidence regarding the importance of the MPML and MPTL ligaments continues to unfold[46,47,69–71].
These ligaments have been found to be important during terminal knee extension\cite{74,75} to counter the lateralizing quadriceps vector, as well as during deep flexion to counter lateral patellar translation\cite{47,51}. The current body of evidence suggests these ligaments can be reconstructed as an adjunct to MPFL reconstruction. Hinckel et al has proposed six clinical situations that augmentation of an MPFL reconstruction with an MPTL reconstruction should be performed\cite{47,76}.

These include patients with the following findings: 1) extension subluxation, 2) flexion instability, 3) skeletal immaturity with risk factors for recurrence, 4) hyperlaxity associated knee hyperextension, 5) increased Q-angle or TT-TG due to increased knee rotation with normal tibial tuberosity position 6) Mild risk factors that do not warrant bony deformity correction such as tibial tuberosity osteotomy (TTO). Thus far, a systemic review\cite{77} suggests that the reconstruction of the MPTL leads to favorable clinical outcomes and supports the role of the procedure as a valid surgical patellar stabilization procedure, particularly when adjunct to MPFL reconstruction \cite{47,74,76,78-81}. Figure 4, shows an MPFL plus MPTL reconstruction.

More research is needed to determine if one technique offers superior clinical outcomes to the others. Furthermore, the benefits of more anatomic multi-ligament reconstructions, and which clinical scenarios benefit the most from these adjunctive soft tissue reconstructions, have yet to be defined.

Balancing the soft tissue restraints: addressing the lateral retinaculum
The lateral patellar soft tissues can contribute in various mechanisms to lateral patellar instability and to medial patellar instability. These soft tissues may be excessively tight leading to lateral patellar compression syndrome, lateral patellar OA, and/or lateral patellar instability. These laterally based soft tissue patellar stabilizers include the iliobibial band extension to patella (ITB-patella), vastus lateralis, the lateral patellofemoral ligament (LPFL), the lateral patellotibial ligament (LPTL), and the lateral patellomeniscal ligament (LPML)[82–85].

Structural/biomechanical analysis suggests that the ITB-patella carries the most load of these fibers[86]. Furthermore, Cancienne et al demonstrated in cadaveric specimens that lateral retinaculum release results in 30% increased lateral patellar translation in full knee extension and 6-9% more translation at 10-90° of flexion[87]. This highlights the importance of the lateral retinaculum in lateral, in addition to medial, stabilization of the patella.

Evaluation of pathology in the lateral patellar soft tissue structures is primarily based on focused physical exam (patellar glide test, <1 quadrant of medial displacement; medial patellar tilt test, <0°)[36,82,88], and imaging (patellar tilt >20°)[82]. It is important to be cognizant of other factors that may complicate or give rise to false positive/negative testing. This may include medial restraint insufficiency leading to lateral patellar subluxation, trochlear dysplasia or increased lateral quadriceps vector leading to increased radiographic patellar tilt but with a redundant lateral retinaculum seen on axial advance imaging [82].
In the setting of patellar instability, if the lateral retinaculum is determined
to be tight and contributing to the lateral patellar instability it may be corrected
via a limited lateral retinaculum release (LRR), lateral retinaculum lengthening
(LRL)[82], or a lateral retinaculum plasty (LRP)[89]. These procedures should not be
performed in isolation for patellar instability as they do not address the underlying
pathology and only serve as an adjunct to overall correction of patellar tracking.

When considering between the laterally based procedures, the LRR has
been associated with inferior outcomes as compared to LRL. Two prospective
randomized studies have shown improved return to sport and functional knee
outcomes after LRL compared to LRR[90,91]. Additionally, when comparing MPFL
reconstruction with LRR or LRP, the LRP resulted in a greater Kujala score and less
medial patellar excursion[89].

Furthermore, insufficiency of the lateral patellar soft tissue restraints may
cause medial patellar instability, which is usually due to iatrogenic over release of
lateral structures or hyperlaxity from collagen disorders. As with lateral patellar
tightness, physical examination is key in the diagnosis, as imaging may not always
show abnormalities. A positive medial glide test, positive medial apprehension
test[92,93], and/or positive gravity subluxation tests[94] are all suggestive of lateral
insufficiency[82]. Medial subluxation may be seen in some cases on imaging in
extension in isolated medial instability or in progressive flexion if combined
medial/lateral instability[95,96]. If the lateral retinaculum has been determined to
be insufficient, restoring its integrity is usually sufficient to restore patellar stability
and improve symptoms. Options for restoring lateral patellar soft tissue tension begin with open lateral retinaculum closure. If tissue closure is not possible due to poor tissue quality/length or will lead to over tensioning of the lateral structures, a lateral retinaculum reconstruction (tissue augmentation or LPFL/LPTL reconstructions) is indicated\[82,85,97–100\]. Augmentation of the lateral soft tissue structures with a collagen sheet (IT band allograft or dermal allograft) is preferred to LPFL or LPTL reconstructions given the paucity of understanding of the anatomy/biomechanics/metric behavior of this ligaments\[82\].
Box 1
Key articles


Box 2
Validated outcome measures and classifications

- Banff patellofemoral instability instrument 2.0
- Norwich Patellar Instability Score
- Kujala Anterior Knee Pain Scale
- Dejour trochlear dysplasia classification
Box 3
Key issues of patient selection for surgical treatment

- Recurrent patellar dislocation
- Chondral / osteochondral injury after a first-time patellar dislocation
- High likelihood of recurrence after a first-time patellar dislocation when two or more of the following risk factors are present (relative indication):
  - Patella alta
  - Trochlear dysplasia
  - Younger patients/ Skeletal immaturity
  - Contralateral dislocation
  - Increased lateral quadriceps vector

Box 4
Special features in the physical examination for the assessment of patellar instability

- Apprehension test
- J sign
- Hyperlaxity (Beighton score)
- Tilt test
- Patellar glide test
- Coronal alignment
- Increased femoral anteversion (Craigs test or increased IR and decreased ER of the hip)

IR: internal rotation; ER: external rotation

Box 5
Tips & tricks

- Obtain a perfect lateral view during fluoroscopy to localize properly the radiographic point for the MPFL (posterior condyles should overlap)
- Use both intraoperative fluoroscopy and anatomical landmarks (medial epicondyle and adductor tubercle) during femoral tunnel positioning to improve precision and accuracy
- Test the metrics behavior of the MPFL (should be slight loose in flexion)
- Consider lengthening a tight lateral retinaculum (<1 quadrant of medial displacement, medial patellar tilt test <0°)
- Allow 1-2 quadrants of patellar displacement medial and lateral to avoid excessive pressure
- Consider MPTL reconstruction in certain cases (hyperlaxity, extension subluxation, skeletal immaturity with risk factors for recurrence, flexion dislocation)
MPFL: Medial patellofemoral ligament; LRL: lateral retinaculum lengthening

Box 6
Major pitfalls in the surgical treatment of patellofemoral instability

- Medial dislocation after a non-indicated or excessive lateral retinaculum release
- Patellar fracture associated with tunnels (higher risk in complete transosseous tunnels that violate the anterior cortex)
- Medial facet hyper pressure, arthritis or pain, secondary to malposition or overtightening the MPFL reconstruction
- Recurrence of patellar dislocation associated with technical mistakes on the MPFL-R or lack of addressing other risk factors present (patella alta, trochlear dysplasia, etc.)

Future Perspectives (Conclusion)

PF instability is a complex pathology as it may result from numerous underlying soft tissue and bony abnormalities. Utilizing a current, evidence-based approach to PF instability offers clinicians both reliable and valid diagnostic tools and proven treatments to best manage PF instability. Approaching PF instability in a patient-specific approach, combined with a shared decision-making process with the patient/family, will guide surgeons to the deliver optimal care for the patellar instability patient.
Figure 1. Treatment algorithm of patellofemoral instability.

MPFL: medial patellofemoral ligament; MQTFL: medial quadriceps tendon femoral ligament; MPTL: medial patellotibial ligament; TTO: tibial tuberosity osteotomy
Figure 2. This figure shows the different soft tissues around the patellofemoral joint, including the medial patellofemoral complex (MPFC).

Figure 3. Cadaveric specimen dissection showing the medial patellofemoral complex (MPFC) and the medial patellomeniscal ligament (MPML).

MPML: medial patellomeniscal ligament; MPFC: medial patellofemoral complex; VMO: vastus medialis oblique.
Figure 4. Patient treated with an MPFL plus MPTL reconstruction using a single peroneus longus allograft in double-strand between the patella and the adductor tendon, and then to the proximal tibia for the MPTL reconstruction. The fixation in the patella if inside a tunnel socket (10 x 4.5 mm tunnel) in the proximal third of the patella, sutured to the periosteum of the patella; then with absorbable suture around the adductor tendon; it returns to an anchor fixation in the mid-third of the patella; and is finally fixed to the tibia with an anchor (1 cm distal to the joint, in 90 degrees of knee flexion). In this figure, the MPFL has been already fixed and the MPTL strand is shown externally, for educational purposes, before its fixation.

MPFL: medial patellofemoral ligament; MPTL: medial patellotibial ligament.
Figure 5. Dissection showing the lateral soft tissues of a left knee with the lateral retinacular lengthening in two layers: a superficial layer and a deep layer that includes the lateral patellofemoral ligament (LPFL). LPFL: lateral patellofemoral ligament.
<table>
<thead>
<tr>
<th>Individual Risk factors</th>
<th>Age</th>
<th>Sex</th>
<th>BMI</th>
<th>Skeletal Maturity</th>
<th>Trochlear Dysplasia</th>
<th>Patellar Height</th>
<th>Increased lateral quadriceps vector</th>
<th>Patellar Tilt</th>
<th>Activity level</th>
<th>Contralateral PF Instability</th>
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<tr>
<td>Arendt, 2018</td>
<td>-</td>
<td>ns</td>
<td>-</td>
<td>Open Phyes</td>
<td>Sulcus angle ≥ 154 ° IS ≥ 1.3 ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
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<td>ns</td>
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<tr>
<td>Jaquith and Parikh, 2017</td>
<td>≤14yo</td>
<td>ns</td>
<td>-</td>
<td>Open Phyes</td>
<td>Dejour A-D CD &gt; 1.45 -</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
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<tr>
<td>Lewallen, 2015</td>
<td>&lt;25</td>
<td>ns</td>
<td>ns</td>
<td>Open or Closing phyes</td>
<td>Dejour A-D CD or IS &gt; 1.2 -</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Huntington, 2019</td>
<td>≤14-18yo</td>
<td>ns</td>
<td>ns</td>
<td>-</td>
<td>Dejour A-D CD &gt;1.2-1.45 IS &gt;1.2-1.3 TT-TG &gt;14-20mm ns</td>
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<td>ns</td>
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<tr>
<td>Balcrek, 2013</td>
<td>≤16yo</td>
<td>ns</td>
<td>ns</td>
<td>-</td>
<td>Dejour A (low), B-D (high) ns</td>
<td>ns</td>
<td>ns</td>
<td>&gt;20°</td>
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<tr>
<td>Hevesi, 2019</td>
<td>&lt;25yo</td>
<td>Low BMI</td>
<td>Open phyes</td>
<td>Dejour A-D CD ≥1.3 TT-TG/PL ≥ 0.5 -</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Martinez-Cano 2021</td>
<td>&lt;21yo</td>
<td>ns</td>
<td>ns</td>
<td>-</td>
<td>Dejour B-D CD ≥ 1.15 -</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

yo: years old; BMI: body mass index; IS: Insall-Salvattii; CDI: Caton-Deschamps; TT-TG: tibial tuberosity-trochlear groove distance; TT-TG/PL: tibial tuberosity-trochlear groove distance / sagittal patellar length; ns: non-statistical difference; - not evaluated
Table 2: Summary of studies reporting risk of recurrence with multiple concurrent risk factors.

<table>
<thead>
<tr>
<th>Number of Risk factors</th>
<th>Risk of Recurrence (%)</th>
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<td>Lewallen, 2015</td>
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<td>Martinez-Cano, 2021</td>
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</tbody>
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Legend:
- Risk factors for Arendt, 2018 were open growth plates, sulcus angle > 154 degrees, IS > 1.3.
- Risk factors for Jaquith and Parikh, 2017 were trochlear dysplasia, history of contralateral patellar dislocation, skeletal immaturity and a CDI > 1.45.
- Risk factors for Lewallen, 2015 were patella alta (IS or CD > 1.2), trochlear dysplasia and chronological age < 25.
- Risk factors for Martinez-Cano, 2021 were patella alta (CD ≥ 1.15), trochlear dysplasia (Dejour types B, C, and D) and chronological age < 21.

(adapted from Factors associated with increased risk of recurrence after first-time patella dislocation: A systematic review and meta-analysis., Huntington, et al., AJSM 2019; 1–11. doi:10.1177/0363546519888846)
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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.

☐ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: