Lateral Patellar Dislocation

A Critical Review and Update of Evidence-Based Rehabilitation Practice Guidelines and Expected Outcomes

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Abstract

» Nonoperative treatment of a lateral patellar dislocation produces favorable functional results, but as high as 35% of individuals experience recurrent dislocations.

» Medial patellofemoral ligament reconstruction is an effective treatment to prevent recurrent dislocations and yield excellent outcomes with a high rate of return to sport.

» Both nonoperative and postoperative rehabilitation should center on resolving pain and edema, restoring motion, and incorporating isolated and multijoint progressive strengthening exercises targeting the hip and knee.

» Prior to return to sports, both functional and isolated knee strength measurements should be used to determine leg symmetry strength and to utilize patient-reported outcome measures to assess the patient's perceived physical abilities and patellofemoral joint stability.

The patellofemoral joint acts as a dynamic pulley system enabling the quadriceps muscles to produce power and function. Injury to the joint can lead to recurrent instability, dysfunction, and persistent pain[1]. Primary lateral patellar dislocation can hinder a patient's function, can interfere with athletic performance, and can increase the risk of episodic instability[1-6]. Most commonly, patellar dislocations occur while participating in sports (61%)[1] and typically occur with the knee in a valgus and flexed position with the foot externally rotated (Figs. 1-A and 1-B)[2-5].

The overall annual incidence of a first-time patellar dislocation is 23.2 per 100,000 person-years and increases to 147.7 per 100,000 person-years in adolescents who are 14 to 18 years of age[2]. Fithian et al. reported that the lateral patellar dislocation risk was highest among girls who were 10 to 17 years of age, and patients with a prior dislocation exhibited a 7 times higher likelihood of subsequent instability episodes[1]. The rate of recurrent dislocation ranges from 7.7% to 13.8% for those with no risk factors to as high as 70.4% to 78.5% for those with 3 risk factors[4,6]. Important risk factors include age of <18 years, an open physis, patella alta, an elevated tibial tuberosity-trochlear groove (TT-TG) distance, and trochlear dysplasia[6] (Table I).

Because patellar dislocations commonly affect young athletes[7], return to sport is a primary goal of treatment. Although patellar dislocations can be treated operatively or nonoperatively, rehabilitation is a key component of both treatment plans[8-10]. The purpose of this article was to provide a critical analysis of current strategies and success of rehabilitation following nonoperative and operative treatment for lateral patellar dislocations.

Patellofemoral Anatomy and Biomechanics

The complex interaction of patellar stability involves a balance between the patellofemoral stabilizing ligaments, osteoarticular surfaces,

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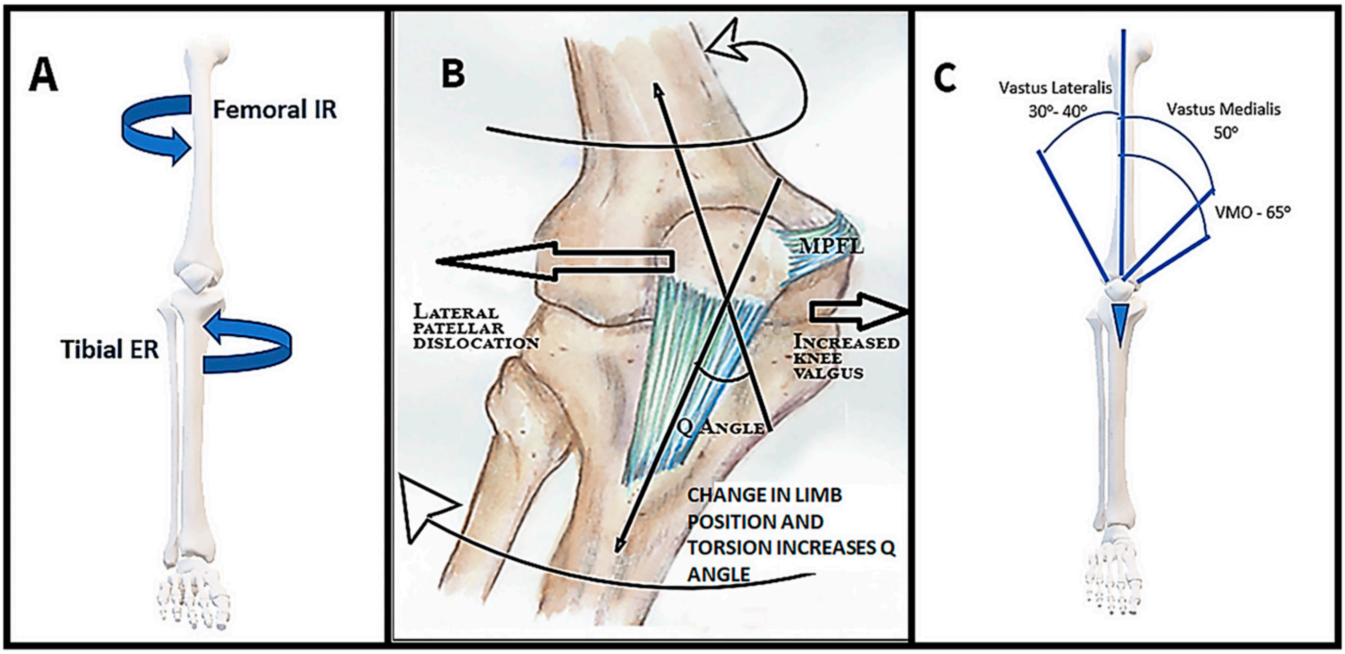

Fig. 1

Figs. 1-A and 1-B Pathomechanisms of a typical lateral patellar dislocation. IR = internal rotation and ER = external rotation. **Fig. 1-C** The quadriceps geometric angles of insertion relative to the anatomical axis of the femur allow a balance of muscular action to provide dynamic patellar stability.

and the dynamic muscular actions of the quadriceps muscles[11]. Maltracking and secondary instability of the patellofemoral joint can be caused by a disruption in the stabilizing forces that these structures provide during functional movement[11]. Anatomical characteristics including the lateral trochlear slope and the quadriceps (Q)-angle can substantially influence patellofemoral joint stability[11-14]. An increased Q-angle shifts the patella laterally between 20° and 60° of flexion, which can precipitate lateral patellar dislocation or increase lateral patellofemoral contact pressures[14].

It was previously thought that the lateral stability of the patellofemoral joint was primarily provided by the medial patellofemoral ligament (MPFL)[11,15-18], but recent literature has indicated that the MPFL is just 1 component of a broader stabilizing structure with both osseous and soft-tissue attachments, the medial patellofemoral complex (MPFC)[19]. The MPFC is composed of the MPFL, which attaches to the patella, and the medial quadriceps tendon-femoral ligament (MQTFL), which attaches to the deep quadriceps tendon[19]. Loeb and Tanaka reported that 57.3% of MPFC fibers attach to the patella and 42.7% of MPFC fibers attach to the quadriceps tendon[19]. The greatest change in the strain of the MPFC occurs between 25° and 30° of flexion as the patella engages with the trochlea. Thus, a tear of the MPFC results in maltracking, lateral translation, and increased contact pressures of the lateral trochlea. At >60° of knee flexion, lateral stability is primarily provided by trochlear engagement[19]. It has been postulated that the medial patellotibial ligament (MPTL) and the medial patellomeniscal ligament (MPML) are the distal

TABLE I Risk Factors for Recurrent Lateral Patellar Dislocation*

Risk Factor	Odds Ratio†	P Value
Chronological age <18 years	2.61 (1.90 to 3.57)	<0.00001‡
Open physis	2.72 (1.85 to 3.99)	<0.00001‡
Sex	1.08 (0.91 to 1.29)	0.39
History of contralateral knee patellar dislocation	2.05 (0.85 to 4.94)	0.11
Patella alta	2.38 (1.32 to 4.29)	0.004‡
Elevated tibial tuberosity–trochlear groove distance	2.87 (1.81 to 4.55)	<0.00001‡
Trochlear dysplasia	4.15 (1.42 to 12.15)	0.009‡

*The pooled data results were obtained from Huntington LS, Webster KE, Devitt BM, Scanlon JP, Feller JA. Factors associated with an increased risk of recurrence after a first-time patellar dislocation: a systematic review and meta-analysis. Am J Sports Med. 2020 Aug; 48(10):2552-2562 †The values are given as the odds ratio, with the 95% confidence interval in parentheses ‡Significant.

medial stabilizers checking the lateral patellar translation, patellar tilt, and rotation at >45°of knee flexion[13,17]. However, the true function of these structures is undetermined[19].

The patella's engagement with the trochlear groove at approximately 30° of knee flexion also aids in patellofemoral joint stabilization. From 0° to 30° of knee flexion, the patella is mobile and relies on the MPFL for stability and proper alignment[20,21]. Tibial rotation and tensioning of the MPFL work together to capture the patella within the trochlear groove[22,23]. Tibial internal rotation on the femur during knee flexion from 0° to 30°, commonly referred to as the "screw-home" mechanism[20-23], increases patellofemoral joint stability and alignment during knee flexion and extension[22]. As flexion increases, the patellar and femoral trochlear groove articulation becomes congruent, providing inherent stability and equilibrium[23,24].

The quadriceps lines of action and patellar muscular wrapping supply active patellar knee stability (Fig. 1-C). Correspondingly, the vastus medialis (VM) and vastus medialis obliquus (VMO) provide a substantial lateral patellar translation counterforce[25-28]. The VM patellar insertion is in the central region of the patella, inserting at a 50° angle to the longitudinal patellar alignment. The VMO inserts at a 65° angle directly into the patella while merging with the MPFL[20,21,25,26]. The MPFL is a continuation of the deep retinacular surface of the VMO[26]. The weakness of the VMO enables increased lateral patellar translation during knee extension[28] and correlates with patellofemoral pain[29]. An increase of the vastus lateralis (VL) pull vector increases the risk of patellofemoral pain and instability[25,30,31]. Patients with poor extensor mechanism alignment have demonstrated both decreased and delayed activation of the VM, causing an increased lateral patellar tilt[29,32]. Furthermore, patients with patellar instability display a more proximal VM insertion with diminished patellar coverage relative to controls. The VM insertion point of patients with patellar instability was frequently found in the medial retinaculum, instead of directly attached to the patella[33]. This could indicate that, following a primary injury, the distal VM insertion scars down within the medial retinaculum.

Treatment Strategy

The ideal treatment strategy following primary lateral patellar dislocation is controversial. Choosing the best treatment strategy is important to minimize the risk of persistent pain, recurrent dislocation, impaired function, and accelerated patellofemoral osteoarthritis. Patients with a history of patellar dislocation have a higher risk of developing osteoarthritis compared with controls without dislocation[34]. The incidence of osteoarthritis following patellar dislocation has been reported to be 1.2% at 5 years and increased to 48.9% at 25 years after dislocation. Factors contributing to osteoarthritis risk include recurrent patellar dislocations, osteochondral injury, and trochlear dysplasia[34]. The clinical challenge is determining who is at the highest risk for recurrent dislocation and how to balance these risks against those of operative treatment.

Several systematic reviews and meta-analyses have attempted to further elucidate whether operative or nonoperative treatment is the best option following primary lateral patellar dislocation. The resounding result from these studies is that the rate of recurrent patellar dislocation is lower with surgical treatment compared with nonoperative treatment[35-39]. In a randomized trial, Bitar et al.[40] demonstrated favorable results for MPFL reconstruction; the mean Kujala Anterior Knee Pain Scale score was significantly greater ($p = 0.001$) in the operative group (88.9 points) compared with the nonoperative group (70.8 points)[40]. Additionally, the nonoperative group experienced a 35% recurrent dislocation rate, and none was reported in the MPFL reconstruction group[40].

Mehta et al.[41] proposed an algorithm for evaluating and treating acute patellar dislocations, advocating for radiographs at the initial assessment to detect a displaced osteochondral fragment and a magnetic resonance imaging (MRI) scan if hemarthrosis is present. The Patellar Instability Severity Score (PISS) incorporates well-known demographic and anatomical risk factors to calculate a patient's risk of recurrent dislocation, helping to stratify patients who would do better with nonoperative treatment than surgical treatment (Table II)[42]. Patients who scored between 4 and 7 points demonstrated a 5 times greater risk of recurrent dislocation within a 2-year period[42]. Patients who have a PISS of <4 points and display normal or mildly dysplastic patellofemoral joint images are good candidates for conservative rehabilitative treatment[35,43-45].

Overall, persistent patellofemoral instability is the most relevant indication for reconstruction, which results in improved functional outcomes at short and long-term follow-up[46-51]. MPFL reconstruction is a viable choice for patients who present with a high-risk PISS of ≥4 points, have undergone failed conservative treatment, or have imaging studies that document a rupture of the MPFL and the desire to return to athletic participation[46,52].

In addition to MPFL reconstruction, other surgical treatment options for correcting patellofemoral instability include tibial tubercle osteotomy (TTO) or trochleoplasty. Patients may require these procedures alone or in addition to MPFL reconstruction, based on the patient's anatomy (e.g., patella alta or trochlear dysplasia) or the desire to offload a patellar cartilage lesion[8,53]. There is limited research examining the effectiveness of combined TTO and MPFL reconstruction in patients with patellar instability. A recent systematic review exploring the effectiveness of TTO with MPFL reconstruction revealed no consensus threshold at which the patellofemoral axis requires TTO compared with MPFL reconstruction alone[54]. Mulliez et al. performed a large prospective study of 129 knees comparing MPFL reconstruction alone and TTO with MPFL reconstruction, which

TABLE II Patellar Instability Severity Score*

Risk Factors	Points
Age	
>16 years	0
≤16 years	1
Bilateral instability	
No	0
Yes	1
Trochlear dysplasia	
None	0
Mild	1
Severe	2
Patellar height	
≤1.2	0
>1.2	1
Tibial tuberosity-trochlear groove	
<16 mm	0
≥16 mm	1
Patellar tilt	
≤20°	0
>20°	1
Total points†	0-7

*Adapted from: Balcarek P, Oberthür S, Hopfensitz S, Frosch S, Walde TA, Wachowski MM, Schüttrumpf JP, Stürmer KM. Which patellae are likely to redislocate? Knee Surg Sports Traumatol Arthrosc. 2014 Oct;22(10):2308-14. †A score <4 represents a low risk of redislocation, while a score ≥4 is associated with a high risk of recurrence.

revealed no significant differences in both Kujala scores and Knee Injury and Osteoarthritis Outcome Scores (KOOS)[55]. Although this study showed no differences in patient outcome scores, TTO with MPFL reconstruction yielded good results for patients in whom the TT-TG distance and patella alta were major contributors to patellofemoral instability[55]. The indications for trochleoplasty include a Dejour type-B or D trochlea with a trochlear depth of <3 mm, a supratrochlear spur of >5 mm, and recurrent instability[56]. This demonstrates that a clear understanding of a patient's individual anatomy is vital when choosing the optimal surgical procedure.

Nonoperative Rehabilitation

Although nonoperative management remains the primary treatment of choice for the management of most first-time patellar dislocations, the treatment strategy and outcomes for nonoperative management are relatively underreported. Most research to date has focused on surgical outcomes, with relatively little focus on the outcomes of conservative treatment[57]. Treatment should balance soft-tissue healing and focused physical therapy. Initial rehabilitation should incorporate bracing, edema management, protected weight-bearing, range of motion, and strengthening of the hip and knee complex (Table III)[57].

Immobilization and Bracing

Immobilization yields variable results, but cast immobilization has produced inferior functional outcomes, longer rehabilitation time, and impaired range of motion[57-61]. Nonoperative rehabilitation protocols vary with regard to range-of-motion restrictions and progression after patellar dislocation. Early knee mobilization is important to cartilage health, and goals of early rehabilitation include achieving full range of motion within 6 weeks[12,57,61].

Dynamic patellar realignment bracing demonstrates a stabilizing effect during weight-bearing between 0° and 30° of knee flexion[62]. MRI and biomechanical studies have validated that patellar realignment braces reduce lateral patellar gliding and facilitate patellofemoral alignment during motion[63-66]. McConnell patellar taping is another commonly advocated technique intended to improve patellofemoral tracking. McConnell taping produces a patellofemoral inferior shift[67], but MRI analysis does not support the use of taping as a medial correction technique[68]. Additionally, McConnell taping has been hypothesized to improve VMO activation; however, there is no direct evidence that taping changes electromyographic activity of the VMO or VL[69,70].

Weight-Bearing

Hilber et al. examined 12 nonoperative rehabilitation protocols and reported that 50% of these protocols did not allow for full weight-bearing until after 5 weeks of protected weight-bearing[61]. At 9 weeks, 100% of the protocols allowed for full weight-bearing. Weight-bearing progression is intended to reduce pain while allowing time to recover quadriceps strength and protect against subsequent subluxation or secondary dislocation[12]. Whereas prolonged weight-bearing protection can thwart the recovery process, early progressive weight-bearing has a positive effect on Kujala scores[57].

Therapeutic Exercise

Utilizing a combination of hip and knee exercises in rehabilitation of the patellofemoral joint is fundamental because both proximal and multijoint exercises facilitate pain reduction and improved function compared with isolated knee strengthening[71-77]. Weakness of the hip musculature can lead to increased femoral adduction and medial rotation during dynamic, weight-bearing activities. These forces can increase stress on the lateral patellofemoral joint vector, which could precipitate further injuries or pain[78]. Moiz et al. advocated both open and closed chain exercises that emphasize quadriceps and hip abductor activation, while also incorporating proprioceptive

TABLE III Nonoperative Treatment Recommendations

Intervention	Clinical Recommendation
Immobilization with removable posterior splint or flexion-resistant knee brace locked at 0° to 20°	**No consensus**[57,59,60,107] Immobilization for 2 to 3 weeks, not to exceed 6 weeks
Immobilization with casting	**Not recommended**[57-59] Marked thigh atrophy, increases knee stiffness
Patellar stabilizing knee brace	**Recommended**[60-65] Stabilizes the patella, allowing early mobilization[60] Positive effect on patellar alignment[61-65]
Taping	**Not recommended**[67-70] McConnell taping causes inferior shift of the patella[67] No effect for medial correction technique[68] Does not alter electromyographic activity in VMO or VL[69,70]
Protected weight-bearing	**Recommended**[57-61] Partial weight-bearing for 0 to 2 weeks, 50% to weight-bearing as tolerated for 3 to 4 weeks weaning off crutches, full weight-bearing by 6 weeks[57,61]
Compressive cryotherapy	**Recommended**[108-111] Apply immediately to 1 to 3 days after the injury[110,111] Decreases inflammatory cytokines[108,109], increases anti-inflammatory cytokines[108,109], decreases edema[108-111], decreases nerve conduction velocity[108,109], increases pain tolerance[108,109,111], increases tissue healing[108,109]
Therapeutic knee range of motion exercises	**Recommended**[12,57,61] Facilitate early mobilization with full range of motion by 6 weeks
Closed and open chain strengthening exercises	**Recommended**[12,57,61,71-77,112] Isotonic quadriceps and hip progressive resistive exercise[57,61], proprioceptive training[57,61], stationary bike[57], proximal and multijoint focused exercises[71-77,112]
NMES of quadriceps	**Recommended**[82-86] Decreases pain[82,83], increases strength[82-86], reduces atrophy associated with immobilization[84]

activities[57]. This global approach to therapeutic exercises is advantageous because quadriceps weakness is a common clinical finding in patients with patellar injuries and patellofemoral anterior knee pain[79,80]. Additionally, targeting the hip and quadriceps improves functional outcomes in patients with patellofemoral pain measured during short-term, intermediate-term, and long-term follow-ups[74]. In a randomized controlled trial of quadriceps exercises following first-time patellar dislocation, general quadriceps (GQ) strengthening exercises led to a significant improvement in functional outcome and activity levels at 12 months, as measured by the Lysholm Knee Scale score ($p = 0.05$) and Tegner activity level ($p = 0.04$), compared with isolated VM exercises[81]. However, these results did not reach clinical importance, indicating that, in practice, there may be no benefit of one quadriceps strengthening regimen over another.

In addition to muscular strengthening, neuromuscular electrical stimulation (NMES) is an effective strengthening modality following knee injuries[82-86]. NMES minimizes atrophy associated with immobilization in terms of both thigh muscle size and mass[84,85]. When utilizing NMES for patellofemoral pain, targeting the VM has demonstrated positive effects utilizing the following parameters: initiate with first treatment, raise the amplitude to elicit visible muscle contraction, and stimulate a minimum of 12 to 15 contractions per treatment session[82,83].

Overall, during conservative treatment, clinicians must prioritize the required healing time, resolution of edema and pain, restoration of motion and strength, normalization of gait and progressive return to running, and sport-specific activities. Patients who display recurrent subluxations or dislocations during conservative treatment are likely to continue to dislocate, and nonoperative management may not be the proper plan of care[4,6,44]. If a patient lacks substantial improvement with physical therapy, has an MRI-confirmed MPFL rupture, or continues to exhibit persistent dislocation, then surgical intervention is the next clear choice[42-44].

Postoperative Rehabilitation

To date, there has been no established standard MPFL reconstruction rehabilitation protocol. Lightsey et al. identified 31 different rehabilitation protocols from 155 U.S. academic orthopaedic surgery programs[87], and Hilber et al. identified 27 distinct rehabilitation protocols from 42 European orthopaedic and trauma surgical institutions[61]. Despite the inherent variability among these protocols, several consensus threads are seen among them with respect to postoperative rehabilitation, weight-bearing status, knee bracing, range of motion,

TABLE IV MPFL Reconstruction Treatment Recommendations

Intervention	Clinical Recommendation
Protected weight-bearing	Immediate partial weight-bearing to weight-bearing as tolerated at 1 to 2 weeks[87,89]
	Full weight-bearing at 4 weeks[87,89]
	Full weight-bearing between 3 and 6 weeks[61]
Postoperative knee bracing	Immobilization at 0° of extension[87,89]
	Utilize for 4 to 6 weeks, not to exceed 9 weeks[87,89]
Cryo-compression	Decrease pain and narcotic use[92,94,108,109]
	Increase range of motion[92,94,108]
	Increase weight-bearing tolerance[92,108]
	Apply immediately after surgery[92-94]
Therapeutic knee range-of-motion exercises	Facilitate 0° to 90° by 2 weeks[87,89]
	Knee flexion to ≥120° by 4 weeks[87,89]
	Full range of motion by 6 weeks[61,87,89]
Closed and open chain strengthening exercises	Isotonic quadriceps and hip progressive resistive exercise[57,61,87,89,90], proprioceptive training[87,89], stationary bike[89], proximal and multijoint exercises[71-77,87,89,112]
NMES of quadriceps	Increased knee extension strength[82,86,92], increased single leg squat[92], increased lateral step-up[82,92], increased anterior reach[82,92], increased single leg hop abilities[92], and increased patient-reported outcome measures[82,92]

strengthening, gait progression, and return to sport (Table IV).

MPFL reconstruction protocols are typically composed of 4 phases that account for tissue healing and maturation: (1) the postoperative and protective phase, (2) the intermediate and proliferative phase focusing on progressive weight-bearing and range of motion, (3) the maturation and progressive strengthening phase, and (4) the return-to-sport phase (Table V). The rehabilitation protocols and goals for TTO and trochleoplasty with or without MPFL reconstruction are largely the same as for MPFL reconstruction alone, with the major difference being a delay in weight-bearing and range-of-motion progressions[88].

Protected Weight-Bearing

Weight-bearing recommendations after MPFL reconstruction are variable and surgeon-dependent. Lieber et al. reported that immediate postoperative weight-bearing restrictions were present in 89% of the protocols examined[89]. In 70% of these protocols, immediate partial weight-bearing was the primary recommendation during the first week of recovery, and 50% of the protocols recommended full weight-bearing by 4 weeks[89]. Lightsey et al. reported that 65% of protocols allowed for immediate weight-bearing as tolerated utilizing crutches, with a mean time with crutches of 1.9 weeks and a mean goal for full weight-bearing of 4.7 weeks[87]. Of interest, 13% of protocols recommended toe-touch weight-bearing, which delayed the mean time to full weight-bearing to 6.3 weeks[87]. Hilber et al. found an accelerated progression to full weight-bearing occurred at a mean time of 2.1 weeks[61]. More than 70% of the analyzed protocols recommended full weight-bearing within 3 weeks, and 100% recommended full weight-bearing after 6 weeks[61].

If an osteotomy is performed, patients are typically restricted from weight-bearing from 2 to 6 weeks postoperatively. Motion and strengthening goals remain the same, and target return dates are similar[88].

Knee Bracing and Edema Management

European protocols have emphasized early functional movement without bracing[61], and American protocols have overwhelmingly recommended immediate postoperative bracing (93% to 97%), with 81% prescribing the brace locked in full extension[87,89]. Given that the reconstructed MPFL is unaffected during axial loading with a fully locked knee brace providing rotational protection, the surgeon and therapist can facilitate weight-bearing while accounting for initial healing and safety constraints[11,90,91]. The mean recommended time to discontinue bracing has been reported as between 5.7 and 6.3 weeks, with a range of 2 to 9 weeks[87,89]. Bracing protocols are similar following TTO, with the recommendation to discontinue bracing at 8 weeks[88].

Cryotherapy is beneficial in reducing postoperative pain and narcotic use and improving knee range of motion and weight-bearing tolerance[92]. Cryo-compression therapy has led to a significant reduction ($p < 0.00001$) in pain scores at 48 hours after the surgical procedure[93]. Schröder and Pässler investigated ice compared with cryo-compressive therapy following an anterior cruciate ligament (ACL) surgical procedure[94]. The addition of compression produced less pain and analgesic use at all assessment points and up to 17° greater knee flexion range of motion compared with the ice-only group[94]. The use of cryo-compressive therapy mitigates pain and edema during the postoperative inflammatory response while improving range of motion and knee function, thereby accelerating postoperative knee rehabilitation[92,93].

TABLE V MPFL Reconstruction Phases of Rehabilitation

	Phase 1	Phase 2	Phase 3	Phase 4
Name	Postoperative and protective	Intermediate and proliferative	Maturation and progressive	Return to sport
Time period	0 to 2 weeks	2 to 6 weeks	6 to 12 weeks	>12 weeks
Goals	Protect repaired tissue Decrease edema and pain Prevent muscle inhibition Brace locked in 0° extension (per physician preference) Partial weight-bearing to weight-bearing as tolerated (per physician preference) Range of motion: 0° to 90° (per physician preference)	Continue knee protection (brace unlocked 0° to 90°) Decrease edema and pain Full weight-bearing off assistive device in knee brace Range of motion: full extension, progress flexion as tolerated ≥120° Normal patellar mobility No straight leg raise lag	Normal gait without brace Full range of motion Resolve edema and pain Improve static and dynamic neuromuscular balance Prevent knee valgus with closed chain exercises Improve cardiovascular endurance	Ability to run and cut Able to jump or land with good multiplane knee control Sport-specific practice activities then play LSI ≥90% on strength and functional testing
Treatment	NMES of quadriceps (VMO) Quadriceps sets, straight leg raises, heel slides Ankle and hip strengthening Patellar mobilization (no lateral glides) Cryo-compressive edema management Gait train with assistive device	NMES until no straight leg raise lag Progress quadriceps strengthening Begin floor-based core and hip strengthening Active knee flexion Closed chain gait, weight shift, and strengthening	Advance closed chain quadriceps and hip strengthening Increase cardiovascular endurance: bike and elliptical Core or plank strengthening Progress single leg balance and stabilization	Maximize single leg closed chain strength and dynamic balance Jog to run progression Hop and jump: double leg to single leg Sport-specific training Cardio endurance

Range of Motion

Range of motion is the most frequently cited parameter in guidelines following a surgical procedure[61,87,89]. The most commonly stated goal, listed in 50% to 97% of protocols, was range of motion of 0° of extension to 90° of flexion to be obtained within 2 weeks following a surgical procedure[87,89]. The initial range-of-motion protection and progression of knee flexion are important because the MPFL is not under maximal strain until 120° of knee flexion[91]. The next most frequent range-of-motion goal is 120° of flexion to be obtained between weeks 3 and 4 postoperatively; full knee flexion should occur between weeks 5 and 6 postoperatively[87,89].

Range-of-motion protocols differ slightly if TTO is performed. Some protocols recommend a brace locked in full extension for the first postoperative week, although an emphasis should still be placed on early range of motion to promote blood flow, modulate pain, aid in the prevention of arthrofibrosis, and restore normal movement to the joint[88]. The goal following TTO is full range of motion by 8 weeks[88].

Strengthening

Quadriceps inhibition is a primary sequela following knee surgery, and, therefore, initial quadriceps activation, strengthening, and progression of neuromuscular endurance must be at the forefront during all phases of rehabilitation. Quadriceps sets and straight leg raises are the most frequently recommended exercises listed in the MPFL reconstruction protocols[87,89]. The initial quadriceps activation and setting ensure active initiation of the quadriceps and allow both the patellar tendon and infrapatellar fat pad to remain mobile. This creates active tension to minimize atrophy and to promote normal gliding of their full length[90].

A multitude of other recommended exercises has been identified within MPFL rehabilitation protocols, including straight leg raises, leg presses, mini-squats, step-ups and step-downs, full squats, lunges, wall squats, resisted knee extension, single leg squats, and stationary biking[87,89]. The strengthening focus should follow the same principles as for conservative treatment, incorporating a proximal and multijoint exercise program performed in both open and closed chains[71-77].

Considering the similarities of quadriceps deficiencies and atrophy following ACL and MFPL reconstructions, evidence supports the utilization of NMES to increase quadriceps activation and strengthening in the early phase of rehabilitation[82,84,86,92,95]. NMES treatment frequency is recommended as 2 to 3 times per week over a 4 to 6-week period[82,86,92,95]. Postoperative NMES practice recommendations follow these core parameters: initiate treatment within 3 to 5 days of the surgical procedure, raise the amplitude to elicit a visible muscle contraction, and stimulate a minimum of 10 to 20 contractions per treatment session[82,92]. Based on current evidence, NMES is an effective adjunct to quadriceps strengthening exercises and has demonstrated positive results in improved knee extension strength, patient-reported outcome measures, and single-leg functional performance testing.

Postoperative Gait

Therapy should focus on equal weight distribution during the gait cycle and incorporate closed chain proprioceptive and stabilization activities. Asaeda et al. discovered that patients demonstrated a significant decrease ($p = 0.025$) in the internal knee extension moment prior to MPFL reconstruction[96]. These same patients presented with an additional decrease in the knee extension moment at 3 months after MPFL reconstruction; the knee flexion

TABLE VI Common Patient-Reported Outcome Measures Utilized with MPFL Reconstruction*†

	Patient-Reported Outcome Measures					
	Lysholm[98-100]	LEFS[113,114]	Kujala[98,100]	NPI[98,115]	BPII 2.0‡,[98,116,117]	Tegner[99,100]
Original construct	Ligament instability	Lower-extremity musculoskeletal dysfunction	Anterior knee pain	Patellofemoral instability	Patellofemoral instability	Activity level
No. of items	8	20	13	19	23	10
Range of score (worst to best)	0 to 100	0 to 80	0 to 100	100 to 0	0 to 100	0 to 10
Time to complete	3 minutes	5 minutes	4 minutes	4 minutes	5 minutes	3 minutes
Normative data	Yes, 94 of 100	Yes, 80 of 80; ages 18 to 39 yr	Yes, 100 of 100	No	No	>6 equals, participates recreational or competitive sport
Reliability	ICC, 0.88 to 0.97	r, 0.85	ICC, 0.82 to 0.93	Cronbach's alpha, 0.93	ICC, 0.97	ICC, 0.82 to 0.92
Standard error of measurement	3.2 to 3.6	3.7 to 3.9	0.82 to 3.00	NR	2.13	0.4 to 0.64
Minimal detectable change	8.9 to 10.1	9	13	NR	6.2	1.0
MCID	NR	9	NR	NR	6.2	NR

*Some data were obtained from: Hiemstra LA, Page JL, Kerslake S. Curr Rev Musculoskelet Med. 2019;12(2):124-137. †ICC = intraclass correlation coefficient, MCID = minimum clinically important difference, NR = not reported, and LEFS = Lower Extremity Functional Scale ‡The BPII 2.0 is the updated version of the original BPII.

angle was also significantly lower ($p < 0.01$) during the early stance than in the control patients[96]. At both 6-month and 1-year follow-ups, knee kinematics and kinetics displayed no significant differences compared with those of healthy controls[96,97]. With proper focused therapy, patients can expect a return to normal gait mechanics postoperatively.

Patient-Reported Outcome Measures

The utilization of patient-reported outcome measures allows medical professionals to establish baseline measurements for pain, function, and perceived impairments. Subsequent assessments allow clinicians to determine meaningful clinical improvement. There are several patient-reported outcome measures commonly utilized within the literature for patellofemoral instability (Table VI)[98-100]. Currently, only the Banff Patella Instability Instrument (BPII) and Norwich Patellar Instability (NPI) score are designed and tested on large patient cohorts for patellar instability[98]. The BPII assesses quality-of-life measures, and the NPI score evaluates symptoms of instability. There are overlaps and correlations between knee-specific patient-reported outcome measures, but the

TABLE VII Recommendations for Care of Lateral Patellar Dislocation*

Recommendation	Grade of Recommendation
MPFL reconstruction should be offered for patients with a high-risk PISS of ≥4 points, MPFL rupture confirmed by MRI, failed conservative rehabilitation, and desired return to sports.	A
Conservative rehabilitation is a viable option for patients with PISS of <4 points who display normal or mildly dysplastic patellofemoral joint images.	B
Rehabilitation should incorporate initial knee bracing and protected weight-bearing. Restoration of full knee range of motion and weight-bearing should be achieved within 6 weeks after injury or surgery. Strengthening should incorporate both proximal and multijoint exercises performed in both open and closed chains.	C
A functional test should be conducted prior to return to sport. This test should include isolated knee strength assessment, single leg hop testing, and patient-reported outcome measures to assess patients' perceived physical abilities, patellofemoral joint stability, and mental readiness to return to sport.	C

*According to Wright[106], grade A indicates good evidence (Level-I studies with consistent findings) for or against recommending intervention; grade B, fair evidence (Level-II or III studies with consistent findings) for or against recommending intervention; grade C, poor-quality evidence (Level-IV or V studies with consistent findings) for or against recommending intervention; and grade I, insufficient or conflicting evidence not allowing a recommendation for or against intervention.

instruments measure different underlying constructs and are not interchangeable[98,100]. The utilization of disease-specific patient-reported outcome measures, in combination with generic knee outcome and activity measures, while incorporating a psychological outcome measure, would provide a well-rounded evaluation of treatment outcomes[98,100].

Rehabilitation Goals for Return to Sport

There is little evidence as to when it is safe to return to sport. In a recent systematic review, Zaman et al. noted that 96% of the surgical protocols referenced return to sport, but only 66% included an expected timeframe[101]. Furthermore, only 18.9% of the studies included either objective or subjective criteria to determine return to sport within the protocol[101], and 23% of protocols mentioned hop testing or strength assessments as a criterion for return to sport[87]. Lieber et al. demonstrated the substantial variability within protocols in which return to sport relied on time, with a median of 17 weeks (range, 12 to 26 weeks)[89].

In a recent meta-analysis, pooled postoperative data were used to calculate an expected 84.1% return-to-sport rate, a mean Kujala score of 85.8, a Tegner score of 5.7, an estimated recurrent dislocation rate of 1.2%, and a reoperation risk of 3.1%[7]. Platt et al. conducted a more recent systematic review and meta-analysis, reporting an even higher return-to-sport rate of 92.8% at a mean time of 6.7 months postoperatively[102]. Krych et al. examined competitive athletes with a mean age of 17.5 years following a primary MPFL reconstruction[103]. At 6 months, the mean knee extension strength deficit was 21.4% ± 14.3%, and the mean flexion strength deficit was 15.8% ± 10.1%. Athletes were able to return to sport at a mean time of 8.1 ± 3.9 months, and the 2-year outcome scores remained high, with a mean Kujala score of 91.1 ± 6.3 points and a mean Tegner rating of 6 (range, 4 to 9)[103]. At a mean time of 7.4 months after MPFL reconstruction, adolescent athletes demonstrated a quadriceps strength Limb Symmetry Index (LSI) of 85.3% and a hamstring LSI of 95.1%. However, only 63% achieved an anterior reach asymmetry of <4 cm on the Lower Quarter Y-Balance test, and just 32% passed the combined 4 hop tests[104]. The authors recommended that adolescent patients may need prolonged rehabilitation beyond 8 months to allow for satisfactory recovery and return to sport.

Another key component of return to sport is psychological readiness. Using the MPFL-Return to Sport after Injury (MPFL-RSI) score, Hurley et al. reported that the most common reason patients did not return to sport was fear of reinjury[105]. Only one-fifth of patients who did not return to sport cited physical limitations, including pain and feelings of instability, as their main reason[105]. The majority of patients who did not return to sport had low MPFL-RSI scores, indicating lower mental preparedness to return to sport[105]. It is possible that lower MPFL-RSI scores may not correlate with physical limitations, indicating that mental preparedness plays a key role in return to sport following MPFL reconstruction. This study reflects an important component of assessing patients' ability and readiness to return to sport and poses an interesting question for further studies.

Overall, the establishment of an objective, criterion-based return-to-sport functional test, such as those performed for return to sport after ACL reconstruction, should occur prior to clearance for return to sport following a surgical procedure or conservative rehabilitation for patellofemoral instability. Based on the current body of evidence, this functional test battery should aim for a threshold LSI of ≥90% in isokinetic knee extension and flexion strength, single leg functional hop and vertical jump tests, and anterior reach of <4 cm on the Y-balance and should utilize patient-reported outcome measures that indicate high perceived knee function and no perceived instability. An expected return-to-sport timeframe is between 6 months and 1 year following MPFL reconstruction and ≥3 months for conservative treatment[7,61,103,104].

Conclusions

Although there remains debate with regard to the best treatment plan following primary lateral patellar dislocation, several conclusions can be made (Table VII[106]). For individuals over the age of 18 years with a low-risk PISS profile, nonoperative management continues to be the primary treatment strategy. The goals should include knee bracing to stabilize the patellofemoral joint and a course of physical therapy for 12 weeks focusing on isolated and multijoint strengthening in both open and closed chains. There is sufficient evidence to support MPFL reconstruction following primary dislocation in athletes ≤18 years of age with a confirmed MPFL tear. MPFL reconstruction, and any necessary associated osseous or soft-tissue procedures, remains the best plan of care with recurrent dislocation. For both conservative and MPFL reconstruction, a functional test should be conducted prior to clearing a patient for return to sport. The test should include both functional and isolated strength measurements to determine if there is an acceptable LSI in strength. Patient-reported outcome measures should also be utilized to assess patients' perceived physical abilities, patellofemoral joint stability, and mental readiness to return to sport.

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