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Post-operative Rehabilitation for Select Patellar-stabilizing Procedures

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Abstract

The rehabilitation process after surgical intervention for patellar instability warrants special consideration of the anatomy, biomechanics, and surgical procedure to facilitate the best outcomes for the patient. There is a paucity of evidence-based literature regarding post-operative rehabilitation protocols for the patellofemoral (PF) compartment. Recommendations for early rehabilitation (0–6 weeks) after lateral retinacular lengthening, medial PF ligament reconstruction, tibial tubercle osteotomy, and trochleoplastyare reviewed in this article. For each procedure, the following common post-operative rehabilitation focus points are reviewed: Weight-bearing status and brace use, joint range of motion, and strengthening.

Keywords: Patellofemoral, Rehabilitation, Patellar instability.

Introduction

The patellofemoral (PF) compartment has unique biomechanical considerations within the knee joint complex. Clinical presentation, baseline level of function, and post-surgical goals of individuals with PF pathology are quite varied. Rehabilitation following PF surgery should honor these elements in addition to basic temporal healing principles associated with specific technical elements of select PF procedures. These principles will serve as guidelines for managing post-operative rehabilitation. The purpose of this article is to educate the reader on rehabilitation considerations during early post-operative rehabilitation (0–6 weeks) for the following PF surgical procedures used to address patellar instability: Lateral retinacular lengthening (LRL), medial PF ligament reconstruction (MPFL-R), distal tibial tubercle osteotomy (TTO), and trochleoplasty. Other procedures, such as cartilage restoration techniques or non-operative management of lateral patellar dislocation, are common within this population, but fall outside of the scope of this current article. Examples of specific post-operative physical therapy protocols and the physical performance testing protocol we utilize at our center are included in the Appendix.

Early Post-operative Rehabilitation for Select PF Procedures

Early post-operative rehabilitation should balance between protecting the structures influenced by surgery while still working to maintain overall joint health and homeostasis through activity. Joint protection is intended to allow for adequate healing to facilitate graft fixation, bone healing, and pain and swelling control following the procedure. Protection strategies often include a period of restricted weight-bearing (WB), bracing, restrictions on knee range of motion (ROM), and modified lower extremity strengthening activities for a period of time.

WBRestriction and Brace Use

Crutches are useful following knee surgery to offload vulnerable structures. With respect to gait, biomechanical loading conditions are unique at the PF compartment, as it is not subject to same axial loading stress as is the tibiofemoral joint. Typically, there is minimal functional engagement of the patellar articular cartilage with the articular cartilage of the trochlea; compressive forces are relatively low with flat ground walking but concentrated toward the inferior patellar pole, especially in patients with patella alta[1].Consequently, restricted WB following surgery is often more for comfort and to protect the knee from buckling due to quadriceps muscle inhibition. The use of crutches is often a source of frustration for patients but, with proper education by the therapist early on, patients can appreciate the importance of assisted gait to not only provide the benefit of joint offloading during early recovery but also to allow a supportive environment for restoring normal gait kinematics. This is critical for the PF population, as quadriceps dysfunction impairs the loading response of gait. Failure to reinstate normal quadriceps muscle activation for deceleration during loading response often results in subtle, ongoing quadriceps muscle dysfunction, which ultimately may contribute to persistent weakness and faulty movement patterns. Bracing with a hinged device that can control knee motion is useful for limiting excessive tissue stress associated with uncontrolled ROM at the knee joint. Bracing for ambulation during the early recovery period provides protective stabilization. At baseline, quadriceps muscle weakness and dysfunction are of particular

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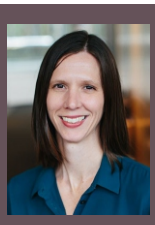
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concern at the PF compartment, as the patella is a central component in the extensor mechanism which is responsible for stability and power at the knee joint through the action of the quadriceps. Patients with PF pathology often have reduced quadriceps muscle strength [2,3]. PF patients may exhibit dysfunctional movement patterns with gait and stairs that may be related to altered quadriceps muscle function[4, 5, 6].The quadriceps muscle has been shown to be subject to inhibition in the presence of an effusion at the knee joint[7,8]. This inhibition response should be heeded not only in the early phases of rehabilitation, when knee effusion is common, but also throughout the protocol progression to avoid setbacks resulting from poorly managed knee effusions. At our center, locking the knee brace at 10° of flexion for knee stability during early ambulation is recommended. Placing the knee in slight flexion reduces the need to circumduct the limb during swing phase with gait, while still not placing the knee into enough flexion to cause concern over creating a flexion contracture. Specific points of concern for WB following PF surgical procedures are patellar translation within the trochlear groove for MPFL-R patients, quadriceps muscle pull at the tibial tubercle for TTO patients, and patellar compressive and shear forces for trochleoplasty patients. The patella is most mobile in early knee flexion when it is not yet fully engaged within the bony confines of the trochlea, which occurs gradually as the knee moves into deeper flexion[9,10]. The MPFL is most important in early knee flexion to stabilize the patella and guide it into the trochlear groove. As the knee continues to flex, the MPFL loses tension and the trochlea provides stability [11, 12, 13]. Thus, the relatively extended knee posture of the joint with gait could make the patella susceptible to increased lateral translation and MPFL stress, especially in the event of a pivoting motion with the foot planted. However, the concern over excessive MPFL graft stress potentially causing elongation and/or pull out is offset by the known strength of the graft and its fixation [14,15].The pull-out strength and stiffness of the allograft reconstructed MPFL reaches or exceeds than that of the native ligament; therefore, early WB with crutches, until a normal functional gait pattern is restored, is recommended at our center to facilitate a balance between symptom management/joint protection and restoration of normal joint properties of mobility, strength, and proprioceptive control following surgery. Bone healing status, at the cortical bone of the tibial tubercle or the subchondral bone of the trochlea, is a worthy consideration for return to WB during the early recovery period following a TTO or trochleoplasty, respectively. Specifically, the primary points of concern are delayed union, loss of fixation, and fracture. Due to limited evidence, it is unclear if fixation strength is adequate to endure the loading associated with normal, full WB functional movements of daily life (i.e.,gait, stairs, transfers); therefore, many post-operative rehabilitation precautions are based on conservative fracture healing principles and timeframes. At our center, we hesitate to enforce a non-WB status following TTO, as it requires holding an extended knee (in a knee immobilizer) in an elevated position through a sustained open kinetic chain (OKC) quadriceps and hip flexor muscle group contraction while crutching throughout the day. A partial WB (PWB) status (≤50% BW) is recommended instead to eliminate the exaggerated OKC quadriceps demand, while still reducing closed kinetic chain (CKC) muscle forces and overall loading through the bone for protected healing. A more conservative WB status may be recommended in the presence of health comorbidities, cognitive impairments affecting a patient's ability to comply with PWB status, or surgeon concern based on intraoperative observations.

Figure 1: Dysfunctional lower body kinematics influence patellofemoral stress, with excessive anterior knee excursion and an upright trunk posture.

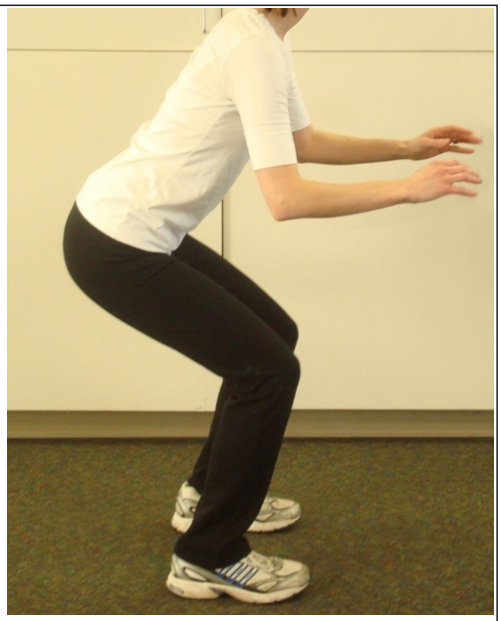

Figure 2: Improved lower body kinematics can reduce patellofemoral stress using a more balanced squatting technique, with flexion more evenly distributed between the lower body joints.

Authors' Recommendations for Crutch and Brace Use in Early Management Phase

LRL

- WB as tolerated (WBAT) with crutches for comfort and symptom control.
- Brace use (locked at 10° knee flexion) to manage quadriceps inhibition.

1. Open or remove brace for sitting and ROM exercises.
2. Gradually open brace for ambulation per improving functional quadriceps control.

MPFL-R

- Concern re: Graft elongation and/or pull-out low.
- WBAT with crutches for comfort and symptom control.
- Brace use (locked at 10° knee flexion) to manage quadriceps inhibition.

1. Open or remove brace for sitting and ROM exercises.

2. Gradually open brace for ambulation per improving functional quadriceps control.

Distal TTO

• PWB (≤50%) with crutches for comfort, symptom control, and osteotomy site protection.

1. After 4 weeks can progress toward full WB (FWB) walking in house with brace locked at 10°.

• Brace use:

1. Locked at 10° for 4 weeks for joint stability (quadriceps inhibition) and protection of osteotomy site (tibial tubercle).

2. Open brace when sitting; remove for knee ROM.

3. After X-ray confirmation at 4 weeks, open brace if not radiographic concerns as per improving functional quadriceps control.

4. Use crutches PWB when brace is open (for longer distance walking).

Trochleoplasty

• PWB (≤50%) with crutches for comfort, symptom control, and reducing stress at trochleoplasty site. May progress to FWB with brace locked when ambulating.

• Brace use (locked at 10°) for joint stability (quadriceps inhibition) and protection of trochleoplasty.

1. After 4 weeks, gradually open brace per evidence of healing at trochleoplasty site and improving functional quadriceps control.

Joint ROM

Early mobility versus immobilization is hotly debated following knee surgery. Immobilization is often encouraged for the sake of managing excessive joint translation and stress, to promote healing of bone and soft tissue and adequate fixation of ligament grafts. Concerns regarding immobilization revolve around the observed biological responses. Early mobilization promotes increased collagen proliferation, organization, and ultimately tissue strength, whereas immobilization can contribute to the leaching of ground substance from the bony attachment zone of the ligament and decrease in the biomechanical properties of the ligament[16,17]. Per a systematic review, early mobilization and WB has not been shown to be deleterious to recovery outcomes following MPFL-R[18]. Similar studies comparing outcomes are not available for the other procedures discussed in this text. The joint-protective function of immobilization, in the form of bracing, does have a role with gait in early rehabilitation, but in general, early ROM with exercise is encouraged after PF surgery to maximize joint nutrition, minimize the risk of joint stiffness, and maintain joint proprioception and comfort. The ROM limitations we enforce at our center are generally brief in duration and are in place to offset concerns over disruptive tension at healing bone (TTO) or soft tissue (LRL) or excessive compressive forces at the articular cartilage (trochleoplasty). In particular, with an LRL procedure, a strategic amount of tissue is released to balance the PF compartment. Excessive stress with ROM into higher knee flexion angles may over elongate this tissue in the early healing phases. However, inadequate tissue stress through complete immobilization may promote excessive tissue stiffening and scarring, thus reversing the desired effect of the procedure. A balance must be struck between reasonable early mobility and excessive tissue stress. We follow the recommendation of the patient staying within a subjective pain/pressure level of 3/10 or less with end range stretching activities to avoid pushing into a zone of excessive tissue disruption. This recommendation is not vetted in the literature but falls into the realm of prudent clinical decision making.

Authors' Recommendations for Early Rehabilitation ROM Precautions

For all

• Full extension encouraged immediately postoperatively.

• Do not force into painful end range knee flexion.

1. Pain level 3/10 or less recommended as long as ROM gains occurring weekly.

2. Consult with surgeon if ROM excessively painful or not progressing as anticipated.

• Control knee swelling. If swelling increases with PROM, reduce knee ROM stretch and concentrate on tissue mobilization and strength.

LRL

• Limit knee flexion ROM to 60° for first 2 weeks postoperatively, then progress to full ROM functionally.

• Avoid end range quadriceps muscle stretching until 8+ weeks postoperatively.

• MPFL-R.

• Gradual progression toward full knee flexion ROM as tolerated.

TTO

• Limit to 90° for first 4 weeks postoperatively.

• Avoid end range quadriceps muscle stretching until 8+ weeks postoperatively.

Trochleoplasty

• Limit knee flexion ROM to 90° for first 4 weeks postoperatively, then gradually progress as tolerated.

Muscle Activation/Strengthening Precautions and Considerations

Exercise selection is critical during the early recovery phases and throughout the entire recovery process following PF surgery, especially with targeted strengthening of the quadriceps muscle. PF compartment stress changes based on many variables: CKC or OKC conditions, angle of knee flexion, variable or constant loading conditions, and underlying kinematics/body position during functional movement.

When it is difficult for the patient to attain a strong volitional quadriceps muscle contraction, the use of biofeedback or neuromuscular electrical stimulation may be useful and is recommended. A strong volitional quadriceps contraction is a prerequisite that must be met before advancing into more difficult strengthening exercises.

PF Compartment Stability with Strength Exercises

The orientation of the patella within the trochlea is a central concern for PF instability. Knowledge of the biomechanics of the PF compartment with different exercise positions and movements is critical for safely progressing strength activities after surgery. Increased lateral patellar translation is observed with quadriceps muscle activation as the knee moves from 40° flexion into full extension (40° to 0°).The

amount of lateral translation is most pronounced in the OKC condition, with an isolated pull of the quadriceps muscle[19, 20, 21].In CKC, the pull of the quadriceps is offset by coactivation of other muscles groups to manage the axial loading forces through the joint. Reduced lateral patellar translation is observed in the CKC condition [19, 20, 21].In deeper angles of knee flexion, the patella becomes stable within the trochlea (the degree varies between individual patients per the morphology of the trochlea). Consequently, the concern over excessive lateral translation is diminished as the knee moves into deeper angles of flexion with exercise. A different set of concerns must be considered for the concept of PF compartment articular cartilage stress.

PF Compartment Stress with Strength Exercises

Much like PF translation, PF compartment stress has also been found to vary per knee flexion angle and exercise position (OKC or CKC). Stress is the product of compressive forces at the joint (generated by quadriceps muscle pulling) divided by the area of contact between the patella and the trochlea. Under constant load (fixed external weight) with OKC knee extension, PF stress remains steady until the knee approaches full extension, where it measures higher [22].Conversely, with a variable load (i.e.,elastic resistance band) PF compartment stress is found to increase as the knee moves closer to full extension. CKC squatting creates relatively low PF compartment stress when performed through shallow angles of knee flexion (0°–45°); however, stress increases with progressively greater squat depth [23]. Lower body kinematics can further influence PF stress, with excessive anterior knee excursion and an upright trunk posture (Fig. 1) compared to a more balanced squatting technique (Fig. 2), with flexion more evenly distributed between the lower body joints [23]. PF compartment stress has been found to increase when the dynamic Q-angle of the lower limb increases or the tibia moves into excessive external rotation or the femur into internal rotation and/or adduction [24, 25, 26]. These are movement patterns commonly referred to as "valgus collapse" at the lower limb. Attention should be given in cuing patient to avoid this movement flaw with CKC exercises (squatting, stepping, and lunging). Exercise selection for safe quadriceps strengthening is a source of great concern and angst in post-operative recovery following TTO due to the direct relationship between the osteotomy site and the pull of the quadriceps muscle through the patellar tendon insertion. Sparse literature exists exploring the strength of the fixation site or the amount of pull at the tibial tubercle generated by common strengthening exercises. The use of TTO procedures for exposing the tibiofemoral joint with revision total knee arthroplasty has increased interest in this particular topic, and two relevant studies were identified regarding fixation strength. Davis et al. investigated load to failure with two different TTO fixation techniques with an applied line of pull along the longitudinal axis of the patellar tendon, parallel to the line of the osteotomy[27].Load to failure was found to be greatest for the two 4.5 mm cortical screws at 1654 ± 359 N. Caldwell et al. also explored TTO fixation strength, applying lines of pull at 0° and 25° from the tibial axis, rather than solely in parallel with the patellar tendon [28]. The resultant load to failure values were 1429 ± 348N at 0° and 1925 ± 982 N at 25° with screw fixation. Davis et al. used vector diagram analysis to estimate average forces placed on the tibial tubercle through the pull of the patellar tendon with the quadriceps strengthening exercises of straight leg raising (SLR) and active knee extension against gravity and arrived at values of 400 N and 250 N, respectively [27]. Powers et al. investigated patellar tendon to quadriceps muscle force ratios in a laboratory setting. Average patellar tendon loading forces were found to be the lowest at 125N at 60° of knee flexion and the highest at 205N at 0° knee flexion with a simulated multiplane loading condition [29]. The measured forces found in this paper are lower than the mathematically estimated values cited by Davis et al.Both sets of values fall well below the load to failure values found for the osteotomy fixation techniques. Similar loading data were not explored for WB tasks with any of these studies. Caution should be taken in translating the findings of these studies to direct clinical practice, as they may not be accurate in real-life conditions, particularly for patients with a higher magnetic resonance imaging, under different angles of loading, or under conditions of greater or more repetitive bony loading encountered with activities of daily living WB and various therapy activities. Hip muscle strength has proven to be relevant for individuals with PF dysfunction[30,31].Hip strengthening continues to be recommended and shows benefit in the PF population[32].Early hip muscle strengthening is generally well-tolerated following PF surgery, as long as consideration is given to patient positioning to avoid stress to the surgical knee. Once the patient has safely progressed through the early post-operative phases, a functional progression of strengthening exercises and overall cardiovascular fitness is recommended. These progressions should be criterion based and well tolerated with respect to symptoms of pain, swelling, or instability. The ultimate goal is to return limb strength to within 90% of the uninvolved side by the completion of supervised care. Consideration should be given to the fact that the entire person has become deconditioned by the injury, and strength of the uninvolved limb may represent a misleadingly low target for return of strength. Similarly, attention should be given to the quality of movement patterns at both limbs, as individuals with PF pathology often exhibit movement faults bilaterally.

Authors' Recommendations for Early Rehabilitation Strength Exercise Selection

For all

• Observe for high-quality quadriceps muscle contraction with volitional activation.

1. Superior patellar translation should be apparent with quadriceps contraction.
2. No obvious cocontraction noted at hamstrings or proximal hip musculature.

• Multiplane hip strength permitted.

1. OKC leg lifting: SLR (flexion) in reduced demand position.
2. Modified bridging with exercise ball under calves.

• General LE strength in CKC.
1. Calf raises.

LRL

• Intensity of quadriceps activation with OKC and CKC strength drills should not cause discomfort ≥3/10 at the surgical site.
• No OKC strength through arc of motion × 4–6 weeks postoperatively.
• OKC drills permitted:
1. Isometric quad contraction in full knee extension.
• SLR (flexion) in reduced demand position.
• Standing or tall sitting.
• Progress toward supine per strength gains (absence of extensor lag).
1. Seated active heel slide into terminal knee extension (TKE) permitted maintaining contact with foot on floor.
• CKC drills permitted:
1. Standing TKE with resistance band.
2. Partial depth squats (twolegs).
3. Marching.

MPFL-R

• Avoid excessive lateral patellar translation.
• OKC drills permitted:
1. OKC quadriceps isometric or isotonic strengthening: 40°+ knee flexion.
• CKC drills permitted:
1. Quadriceps isometric or isotonic strengthening: 0°–40° KF (first 4–6 weeks postoperatively).
1. Partial depth squats (2 legs).
2. Shallow depth step drills.
3. Marching.

Distal TTO

• Avoid excessive isolated patellar ligament stress.
1. No OKC strength through arc of motion.
• OKC drills permitted:
1. Isometric quad contraction permitted.
• SLR (flexion) in reduced demand position.
• Standing or tall sitting.
• Progress toward supine per strength gains (absence of extensor lag).
1. Seated active heel slide into TKE permitted maintaining contact with foot on floor
• CKC drills permitted:
1. Standing TKE with resistance band.

Trochleoplasty

• Avoid excessive PF compressive stress with quadriceps strengthening.
• OKC drills permitted:
1. Isometric contraction in full extension.
1. SLR (flexion) in reduced demand position.
• Standing or tall sitting.
• Progress toward supine per strength gains (absence of extensor lag).
• CKC drills permitted:
1. TKE with resistance band.
2. Isometric leg press (40°–90°) at comfortable level of intensity (not moving the load isotonically).

Summary

Rehabilitation of the post-surgical PF patient must include careful attention to detail of the anatomy and biomechanics of the PF compartment. We have reviewed the rehabilitation process for LRL, MPFL-R, TTO, and trochleoplasty. Surgical procedures and the resultant post-operative precautions vary per surgeon technique and patient population. Communication between surgeon and therapist is imperative for maximizing patient outcomes. Reference the addendum for full post-operative rehabilitation protocols from our center.

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