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Physiotherapy Interventions Combining Continuous Passive Motion and Maitland Mobilization for Patellar Fracture Rehabilitation

Dr. Mridula Mahidhar[1], Dr. Shriya Payasi[2]

[1]Associate Professor,BPT MPT(Orthopedics), MBA (Healthcare & Hospital Management), Director of Balashree Institute of Paramedical sciences Jabalpur (M.P), Department of Physiotherapy, Consultant Physiotherapist, Baderia Metro Prime Hospital, Jabalpur (M.P)

meidulanigam@gmail.com

[2]BPT MPT(Orthopedics), Department of Physiotherapy, Assistant Professor of Balashree Institute of Paramedical sciences Jabalpur (M.P)

shriyapayasi215@gmail.com

Abstract

A common issue following patellar fractures is postoperative pain, joint stiffness, quadriceps weakness, and limited knee range of motion (ROM), all of which may contribute to a suboptimal functional recovery. Early physiotherapy is thus crucial to regain movement and avoid chronic disability. This review aims to provide an overview of current evidence regarding physiotherapy interventions using Maitland Mobilization and passive machine-driven movement (such as Continuous Passive Motion [CPM]) in the treatment of patellar fracture. Review covers rehabilitation challenges, mechanisms and clinical application of CPM, principles of Maitland Mobilization and how this can be integrated with therapeutic exercises. From published clinical studies, CPM appears to encourage early joint motion, reduce joint stiffness and aid to the recovery of ROM, whilst Maitland Mobilization increases accessory joint mobility and helps to relieve pain using graded manual techniques. These interventions are combined with strengthening and stretching exercises and gait training to form a comprehensive rehabilitation approach which improves knee function and functional independence. But more rigorous RCTs are needed to establish standardized REPs and to identify long-term clinical outcomes.

Keywords; Patellar fracture; Continuous Passive Motion (CPM); Maitland Mobilization; Knee range of motion; Physiotherapy rehabilitation.

INTRODUCTION

Patellar fractures are uncommon, but important fractures and make up around 1% of all skeletal fractures. The patellar bone is the largest sesamoid bone in the human body and is an integral part of the knee extensor mechanism, so disruption of the integrity of the patellar bone can have a significant impact on knee stability, extensor strength, and functional mobility [1]. These fractures usually occur after direct impact with the anterior surface of the knee, such as a fall or road traffic accident, or after indirect trauma by sudden (abrupt) strong contraction of the quadriceps muscle. Treatment will depend on the displacement of the fracture, the integrity of the extensor mechanism and patient-related factors, and is usually conservative for fractures that are not too displaced or comminuted, and is surgical for fractures that are too displaced or comminuted [2].

Although many improved techniques exist to fix fractures, complications are still a frequent occurrence after injury and in the post-immobilization period, and often result in poor functional outcome. Some of the most common problems after patellar fracture include joint stiffness, decreased range of motion (ROM), quadriceps muscle weakness, chronic pain, and periarticular adhesions [3]. Arthrofibrosis and soft tissue contracture develop with prolonged immobilization and delayed initiation of rehabilitation, resulting in decreased knee flexion and

extension that has a negative impact on gait, stair climbing and other activities of daily living. Continued quadriceps inhibition further delays recovery of normal knee biomechanics and functional performance [4]

Thus, early rehabilitation is regarded as a key aspect of patellar fracture treatment. Early introduction of controlled joint mobilization and progressive exercise after fracture stability allows helps maintain joint cartilage health, reduce adhesions, maintain muscle strength and promote functional ROM. With the development of modern rehabilitation, early protected motion has been increasingly emphasized to achieve the best clinical results in order to preserve fracture healing [5].

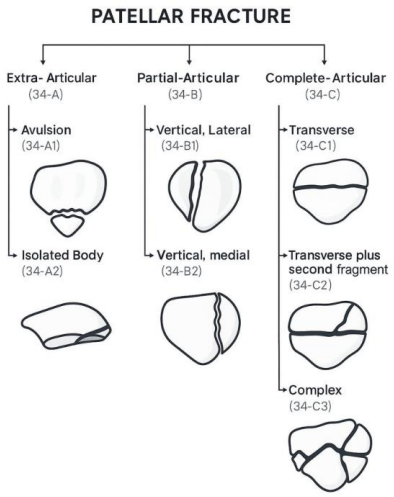

Figure 1: Classification of patellar fractures as per AO/OTA.[6]

Physical therapy is an important aspect of the rehabilitation program after both conservative and surgical treatment of patellar fracture. Typically, treatment includes pain and edema management, range of motion exercises that gradually increase, strengthening of the quadriceps muscles, retraining of gait and functional rehabilitation depending on the stage of healing. CPM has been widely adopted for the purpose of early joint movement, to reduce stiffness and to improve knee ROM and Maitland mobilisation is used to restore accessory joint movement, to reduce pain and to improve functional mobility by using a graded manual therapy technique. While both procedures have proven to be clinically successful on their own, the combination of these two has now been a focus of interest to achieve greater knee ROM and functional outcome after patellar fracture. In this review, therefore, physiotherapy interventions will be explored and a focus will be given to the application of CPM and Maitland mobilization in the rehabilitation of patellar fracture.

REHABILITATION CHALLENGES FOLLOWING PATELLAR FRACTURE

The rehabilitation protocol following patellar fracture is successful if one takes into consideration the anatomical, biomechanical and physiological changes during the healing process. While the union of the fracture is the ultimate goal of treatment, restoration of knee function relies heavily on regaining joint mobility, muscle strength, and functional stability. Various factors such as prolonged immobilization, postoperative pain, soft tissue injury and quadriceps dysfunction may prolong recovery and contribute to the persistent disability. Therefore, rehabilitation protocols need to be tailored to the phase of healing and clinical outcomes need to be monitored continuously to ensure optimal functional outcome [7].

Anatomy and Biomechanics of the Patellofemoral Joint Relevant to Rehabilitation

The patella is the largest of the 9 bones in the sesamoid family and is embedded in the quadriceps tendon and attached to the femoral trochlea to create the patellofemoral joint. It acts as a mechanical lever that helps the quadriceps muscle to generate more moment arm, making it more efficient to extend the knee and less force to expend during activities like walking, climbing up and down stairs and getting out of a chair. As the knee becomes more flexed, the forces acting on the patellofemoral joint increase and increase progressively. Therefore, it is crucial to restore normal patellar tracking and joint mobility during rehabilitation. Any damage to the extensor mechanism, or change in the patellar alignment, could affect the biomechanics of the knee and hinder the patient's functional recovery. Early rehabilitation in the end, therefore, emphasizes restoration of controlled joint motion, preservation of fracture stability and preservation of the integrity of the extensor mechanism [6].

Pathophysiology of Post-Fracture Knee Stiffness

Knees that become stiff after patellar fracture occur frequently and are caused by both biological and mechanical changes. Trauma and surgery trigger an inflammatory process with increased vascular permeability, edema and release of inflammatory cytokines. When joint motion is limited for extended periods, there is excessive deposition of collagen and proliferation of fibroblasts that lead to the development of intra-articular adhesions and peri-articular

fibrosis, which can lead to arthrofibrosis. These changes make the capsule less elastic, decrease the range of motion at the patellar joint and gradually restrict flexing and straightening the knee. Delayed joint mobilization leads to other impairments, including quadriceps inhibition, that contribute to the poor functional recovery and mechanical abnormalities of the joint, thus emphasizing the need to begin controlled movement as soon as fracture stability allows [8].

Factors Limiting Knee Range of Motion

There are a number of interrelated factors that affect recovery of knee range of motion (ROM). Pain also causes a voluntary restriction of movement and can result in protective muscle guarding; postoperative edema causes intra-articular pressure to rise, and joint flexibility to decrease. Immobilization is required in the early stages of fracture healing, but when continued beyond this time will lead to capsular contracture, cartilage breakdown and muscle wasting. The scar tissue formation around the surgical area or the damaged soft tissues may also limit the mobility of the patellar tendon and the excursion of the knee joint. In addition, the muscle inhibition of the quadriceps that occurs following arthrogenic activity decreases joint extension during active rehabilitation and impedes active rehabilitation. Effective physiotherapy, therefore, involves pain control, edema management, slow return to movement and progressive strengthening to reduce these impairments and maximize ROM [9].

Rehabilitation Goals across Different Healing Stages

The goals of rehab depend on how much the tissues have healed. The main objectives of the inflammatory phase are to reduce pain, manage inflammation, protect fracture fixation and prevent secondary complications with proper positioning and controlled and gentle movements. The reparative stage focuses on progressive restoration of knee ROM, patellar mobility, quadriceps activation and progressive weight bearing, as fracture stability allows. The remodeling period is when rehabilitation will concentrate on enhancing muscle strength, neuromuscular control, balance, gait, and functional activities to regain pre-injury performance. These stages are carefully managed to allow for optimal healing of the fracture and prevent stiffness and loss of function [10].

Clinical Outcome Measures

Assessment of rehabilitation outcomes is a crucial component to evaluating recovery and to inform the progression of rehabilitation. Knee ROM is the best measure of improvement in joint mobility and is performed with a universal goniometer. The Visual Analogue Scale (VAS) and/or Numeric Rating Scale (NRS) is commonly used to assess pain intensity. Functional recovery is measured using validated patient-reported outcome tools, such as Lysholm Knee Scoring Scale, Knee Society Score (KSS), and Kujala Anterior Knee Pain Scale that assess knee function, walking, symptoms, stability, and ability to climb stairs. These objective and subjective measures give a holistic picture of treatment effectiveness and enable evidence-based rehabilitation planning [11].

CONTINUOUS PASSIVE MOTION IN PATELLAR FRACTURE REHABILITATION

A frequently employed adjunctive physiotherapy technique to encourage early knee mobility after patellar fracture rehabilitation is Continuous Passive Motion (CPM). CPM is a motorized machine that will give the knee a continuous range of joint movement in a controlled and pain-free fashion, while the knee remains still. Introduced by Salter and colleagues, CPM involves the use of a continuous machine to move the knee without any active muscle contraction. It is often used as part of postoperative rehabilitation following stable fracture fixation to reduce the negative effects of prolonged immobilization and to prevent the healing tissues being compromised. Repetitive passive movement will stimulate mechanoreceptors, keep the joint capsule extensibility, prevent the shortening of periarticular soft tissue, and maintain the alignment of collagen fibers. CPM decreases compression of the patellofemoral joint without the quadriceps contraction, thus allowing the tissues to heal, maintain joint mobility and allowing gradual restoration of functional knee range of motion [12].

Physiological Effects of CPM

CPM has several positive physiological effects that aid in knee rehabilitation. Repeated movements increase the flow of synovial fluid, which increases the transfer of oxygen and nutrients to the avascular articular cartilage and helps to remove metabolic waste products. Greater joint motion also aids in promoting cartilage metabolism, improving lymphatic and venous drainage from the joint, and preventing the build-up of inflammatory fluid. In addition, it helps to prevent the development of intraarticular adhesions and periarticular fibrosis by allowing extensibility of tissues during the immediate postoperative stage. These effects work together to improve knee range of motion (ROM), flexibility and functional recovery [13].

Clinical Protocols

CPM clinical protocols are different depending on the fracture stability, surgical technique and surgeon preference.

CPM is used in most rehabilitation programs beginning within 24–48 hours of surgery after stable fixation has occurred. Initial range of knee flexion is usually between 0° to 30° or 0° to 45° and is increased by 5° to 10° every day as tolerated and as evaluated by the patient. Typical treatment duration is 1-2 hours two to four times per day, and includes exercises to activate quadriceps, progression to weight bearing and functional physiotherapy. Close monitoring is necessary to prevent any increase in ROM that may have a negative effect on fracture healing or worsen pain.

Benefits and Limitations Reported in Clinical Studies

The clinical trials have shown that CPM can help restore the knee ROM earlier, to relieve outcomes after surgery that causes knee stiffness, to help reduce pain, and to improve functional outcomes in the short-term when combined with a comprehensive physiotherapy program. These benefits are especially noticeable early in rehabilitation, during the controlled passive motion period when passive motion is used to reverse the negative effects of immobilization. Evidence of its long term superiority to conventional rehabilitation is not consistent, however. A few systematic reviews have indicated small gains in long-term function, muscle strength or patient-reported outcomes with CPM used in combination with active rehabilitation, but not as standalone therapy. The challenges include practical concerns such as equipment availability, the cost of treatment, patient compliance and variation in clinical protocols which means that each patient and fracture must be treated individually.

Maitland Mobilization and Combined Physiotherapy Approach

A manual therapy technique widely used in musculoskeletal rehabilitation, with the goal of reducing pain, restoring joint mobility and enhancing functional movement post injury, Maitland Mobilization is a widely-used technique. Extended immobilization, postoperative fibrosis, pain, and periarticular soft tissue tightness are common sequelae of patellar fracture that often cause loss of accessory joint motion and therefore limited knee range of motion (ROM) and a delayed functional recovery [14]. The Maitland Concept uses graduated oscillatory mobilisations (Grades I-IV) based on the amplitude of movement and the position in the range of movement. Grades I and II are performed in the pain-free range to reduce pain and muscle guarding during the acute phase while Grades III and IV are performed close to the end range to stretch periarticular tissues, increase capsular extensibility and restore accessory joint motion. Mobilisation is commenced only after a satisfactory fracture stability has been obtained and advanced as per the fracture healing and tolerance of the patient. These therapeutic effects occur by both neurophysiological and mechanical mechanisms - stimulation of articular mechanoreceptors inhibits pain, reduction of muscle guarding, improved synovial fluid distribution, stretching of the joint capsule, and prevention of capsular adhesions. These effects promote normal patellar and tibiofemoral accessory motion and lead to better ROM and functional recovery of the knee [15].

Integration with CPM and Other Physiotherapy Interventions

A multimodal physiotherapy program is essential for optimal rehabilitation after a patellar fracture. CPM is usually applied during early post-operative period to ensure passive knee movement and avoid stiffness, whereas Maitland Mobilization is gradually added as the fracture-healing allows for manual joint mobilization. Active and active-assisted ROM exercises, quadriceps strengthening, hamstring and calf stretching, neuromuscular re-education, balance training and progressive gait training are all used to complement these interventions. In particular, quadriceps activation exercises are of significant importance in overcoming arthrogenic muscle inhibition and restoring knee extensor function. Manual therapy and exercise improves mobility and strengthens the muscles, joints and functional abilities during the rehabilitation process [16].

Comparative and Complementary Roles of CPM and Maitland Mobilization

CPM and Maitland Mobilization share similar goals of enhancing knee mobility but the processes are different, as are their clinical uses. CPM is provided by the use of a device that provides continuous passive physiological movement, and is particularly useful in the early stages of rehabilitation when active motion is restricted. On the other hand, Maitland Mobilization offers therapist directed accessory joint mobilization based on the movement restrictions or pain response of the patient. They are not competing interventions, but rather complement other interventions within a staged rehab program. CPM helps to keep the joints moving, decrease swelling and prevent adhesions during the acute phase, whereas Maitland Mobilization treats chronic capsular tightness and accessory motion deficits. Existing rehabilitation literature is supportive of using these techniques in combination with progressive therapeutic exercise to maximize ROM restoration, minimize pain and increase function after patellar fracture, and future studies with greater high-

quality, randomized controlled trials are needed to determine standardized treatment protocols [4].

LITERATURE REVIEW

(Abrar et al., 2026) [17] Examine and contrast the effects of passive range of motion with joint mobilisation vs continuous passive motion with joint mobilisation on "pain, knee range of motion, and functional status" in patients with post-operative knee stiffness. The "Department of Physical Therapy and Rehabilitation, Hayatabad Medical Complex, Peshawar", was the site of this randomised controlled trial. Sixty patients with post-operative knee stiffness, ages 18 to 55, were divided into two groups at random (n = 30 each). Osteoarthritis and Knee Injury Additionally, Group A's outcome ratings were greater than Group B's, suggesting a stronger functional recovery. While both "passive range of motion with joint mobilisation" and continuous passive motion reduced post-operative knee stiffness, continuous passive motion resulted in superior increases in range of motion and function as well as larger pain reductions.

(Ali & Miller, 2026) [4] Delays in post-operative physical therapy considerably raise "the risk of arthrofibrosis and long-term disability" following comminuted patellar fractures, which are difficult injuries, especially in settings with limited resources. A 40-year-old male with multiple comorbidities "presented 53 days after open reduction and internal fixation (ORIF) for a comminuted patellar fracture", presenting with severe knee stiffness. Knee flexion was restricted to 10°, the Visual Analogue Scale (VAS) pain score was 8/10, the Kujala score was 19/100, and the Lysholm score was 7/100, all of which indicated severe functional impairment. This example shows that even when rehabilitation is started later after a complicated patellar fracture, "a combined CPM and home exercise" regimen can result in significant functional improvement. It presents a workable and successful intervention paradigm for settings with limited resources where delayed rehabilitation is typical.

(Raghav et al., 2018) [16] One of the lower limb joints most vulnerable to injury is the knee. Avoiding worsening signs and symptoms is the first step in treatment. Additional treatment options include "ultrasound therapy, CPM (continuous passive motion)", range-of-motion exercises, heat therapy, and icing the damaged knee and surrounding knee joint. Movement with mobilisation is now a widely utilised treatment regimen for joints with limited range of motion or stiffness. The purpose of the study was to determine how mobilisation with movement compared to traditional therapy for individuals with post-traumatic knee joint stiffness. According to their VAS and goniometry scores (p=0.001), there was a significant difference in both pain and range of motion. The study found that MWM is more successful than conventional therapy (CPM) in reducing pain and improving range of motion in post-traumatic knee joint stiffness, as evidenced by the difference in VAS and goniometry scores between the first and 28th days.

(Jia et al., 2024) [18] Compare the safety and effectiveness of physical therapy alone versus combined CPM for postoperative rehabilitation following knee replacement. Clinical research evaluating the effectiveness of CPM in comparison to physical therapy were retrieved and accessed using "the Embase, PubMed, and Web of Science databases". Review Manager software was utilised to analyse data according to inclusion criteria and determine publication bias. Compared to physical therapy, CPM results in far greater treatment and care expenses. Combining CPM with PT did not considerably increase knee range of motion or patient satisfaction. Additionally, the cost of hospital stays was greatly increased by CPM treatment.

(Sinha et al., 2024) [19] Compare the effectiveness of Maitland mobilisation with traditional physical therapy in reducing pain and impairment in individuals with frozen shoulders. Participants with a diagnosis of frozen shoulder between the ages of 40 and 70 were included in a randomised controlled trial for a minimum of three months. Two groups were randomly selected from among the participants. The "Shoulder Pain and Disability Index (SPADI) and Numeric Pain Rating Scale (NPRS)" were used to evaluate both groups before and after the intervention. However, SPADI and NPRS ratings decreased more in the Maitland mobilisation group than in the control group, indicating improved clinical results. When treating frozen shoulder, normal physiotherapy plus Maitland mobilisation is more effective than standard physiotherapy by itself. Incorporating manual joint mobilisation exercises into therapy plans can enhance patient recuperation and functional results.

(Yin et al., 2022) [20] In order to develop a unique rehabilitation method for individuals with chronic ankle instability, ascertain if normal rehabilitation training in conjunction with the Maitland mobilisation is more successful than "routine rehabilitation training" alone. The 48 participants were split into three groups: CG (regular rehabilitation), SG (sham mobilisation and routine rehabilitation), and EG (Maitland mobilisation and routine rehabilitation). The findings demonstrated that while the

self-report of ankle severity and muscle strength did not improve, "the improvement of SEBT, WB-DFROM, and active ankle range of motion" without pain was more evident in EG than in CG and SG. For patients with chronic ankle instability, routine rehabilitation training plus Maitland mobilisation may be more beneficial in terms of balance and ankle range of motion than routine rehabilitation alone; however, the improvement in muscle strength was not sufficiently noticeable.

(Padasala et al., 2025) [21] evaluating the overall effects of Maitland mobilisation as well as the combination of Mulligan mobilisation with movement (MWM) and therapeutic activities (strength and flexibility exercises) in a patient with knee OA in terms of pain relief, greater knee joint mobility, and functional improvement. In six weeks, a 60-year-old male patient with bilateral OA in the knee received administrative treatment consisting of manual therapy, exercise therapy, and electrotherapy. The Visual Analogue Scale (VAS) pain reduction, the WOMAC score for function improvement, and goniometry for knee range of motion were the primary outcome factors. The VAS pain score dropped to 2/10, while the WOMAC score dropped from 85% to 20%, and the knee flexion increased from 95 to 125 degrees. These results suggest that combined physical therapy is useful for treating osteoarthritis in the knee. A combination of Maitland mobilisation, Mulligan MWM, and therapeutic exercises showed that the treatment was successful in terms of reducing pain, and improving knee ROM.

Table 1: Summary of Literature on Maitland Mobilization, Continuous Passive Motion, and Early Physiotherapy Rehabilitation

Author (Year)	Study Design / Participants	Intervention	Key Findings
Jagtap & Varadharaju lu (2024) [22]	Randomized comparative study; 30 diabetic patients with frozen shoulder and moderate tissue irritability	Group A: Conventional physiotherapy (hot pack, ultrasound, exercises). Group B: Conventional physiotherapy + Maitland Mobilization for 6 weeks (4 sessions/week).	Both groups improved significantly; however, the Maitland group demonstrated significantly greater reductions in pain and disability ($p < 0.001$). The study supports the addition of Maitland Mobilization to conventional physiotherapy for enhanced functional recovery.
Shabiethaa et al. (2023) [23]	Comparative clinical study; 60 patients with patellofemoral pain syndrome	Group A: Tibiofemoral mobilization + conventional therapy. Group B: Maitland Mobilization + conventional therapy for 6 weeks.	Both interventions significantly improved pain, ROM, and function ($p = 0.001$). Tibiofemoral mobilization produced greater improvements than Maitland Mobilization in patients with patellofemoral pain syndrome.
Javaid et al. (2022) [24]	Non-randomized clinical study; 60 patients after Colles' fracture	Maitland Mobilization, Mulligan Mobilization with Movement (MWM), and conventional therapy for 4 weeks	All treatment groups showed significant improvements. Mulligan MWM demonstrated superior pain relief and hand function compared with Maitland Mobilization, although both manual therapy techniques were clinically beneficial.
Hong et al. (2023) [13]	Retrospective comparative study; 68 patients after total knee replacement (TKR) with delayed rehabilitation progress	Continuous Passive Motion (CPM) vs. standard rehabilitation under ERAS protocol	CPM significantly improved knee ROM at discharge (76.0° vs. 68.4°, $p = 0.02$) without affecting pain or quadriceps strength. However, CPM

			increased hospital stay and showed no long-term functional advantage.
Alqahtani et al. (2025) [5]	Cross-sectional comparative study; 132 patients following ACL reconstruction	Early physiotherapy (≤2 weeks) vs. delayed physiotherapy (≥4 weeks)	Early physiotherapy significantly improved knee ROM, quadriceps strength, proprioception, and functional outcomes without increasing graft failure or knee instability, supporting the importance of early rehabilitation.

CONCLUSION

Due to the debilitating pain and stiffness experienced after patellar fracture, along with quadriceps weakness and limitation of range of motion in the knee, structured and early physiotherapy is very important to ensure the best functional outcome following patellar fracture. The evidence available suggests that graded manual techniques of joint mobilization are effective in restoring accessory joint motion, reducing pain and improving knee mobility, whereas passive machine driven techniques, e.g. Continuous Passive Motion (CPM) are useful for early controlled movement, reducing adhesions and reducing the negative effects of extended immobilization. These complementary interventions, combined with therapeutic exercises, progressive strengthening, flexibility training and gait retraining, result in greater ROM, joint function and overall rehabilitation gains when compared to treatment alone. The clinical benefits of Maitland Mobilization and CPM when combined in a multimodal physiotherapy approach are supported by the current studies, but there is currently some uncertainty about the superiority of the combination treatment and optimal dosage in the long-term. To uncover treatment sequence, understand the patient population that is likely to benefit, and to support evidence-based guidelines for patellar fracture rehabilitation, future RCTs with standardised rehabilitation protocols are required.

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