

Postoperative Rehabilitation after Operative Treatment of Tibial Plateau Fractures: A Narrative Review of Safety, Progressive Loading, and Criterion-Based Recovery

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Abstract

Operatively treated tibial plateau fractures may leave persistent deficits in motion, strength, gait, balance, independence, work, sport, and quality of life despite fracture union. This narrative review synthesized contemporary evidence on postoperative motion, loading, exercise, neuromuscular and gait recovery, pain, participation, and patient-centred care. A targeted search of PubMed/MEDLINE, publisher records, and reference lists identified English-language adult studies published from January 2020 through 2 September 2026. Forty-six publications, including 41 original research reports and five reviews, were included. Early knee motion is generally supported when fixation and soft tissues permit. Immediate or earlier weight-bearing may improve clinical, gait, and balance outcomes in selected patients with stable fixation, especially the Schatzker I - IV patterns represented in the available randomized reports, but should not be generalized to mechanically vulnerable constructs or highly comminuted injuries. Recovery may remain incomplete because weakness, gait asymmetry, pain, fear of movement, and participation restrictions can persist after union. Rehabilitation should therefore progress through explicit mechanical, clinical, functional, psychological, and independence criteria rather than one fixed timetable. The proposed pathway is an evidence-informed decision framework and not a validated universal protocol.

Keywords

Tibial Plateau Fracture, Postoperative Rehabilitation, Weight-Bearing, Gait, Functional Recovery

1. Introduction

Tibial plateau fractures disrupt the articular surface, alignment, subchondral bone, and frequently the meniscal, ligamentous, and soft-tissue environment. Fracture morphology and associated injuries can influence early function, while operative treatment aims to create sufficient stability for healing and rehabilitation [1] [2]. Technical success alone does not ensure normal knee function.

Long-term studies document continuing improvement together with persistent limitations in activity, work, sport, and quality of life [3]-[5]. Reduction quality also influences functional potential [6]. Rehabilitation therefore has to balance protection of the reconstruction against preventable stiffness, muscle loss, altered gait, dependence, and fear of movement. Earlier reviews found marked protocol variation and limited direct evidence [7] [8].

Contemporary management reviews describe how fracture morphology, fixation, and soft-tissue injury shape treatment decisions [9] [10]. This review evaluates early motion, progressive versus restrictive loading, exercise, gait, safety, independence, and return to participation. It also relates rehabilitation decisions to fracture classification, fixation stability, age, and bone quality, and proposes a criterion-based pathway for clinical use. Original intervention, longitudinal, mechanistic, and patient-experience studies are discussed within the relevant rehabilitation domains below.

A rehabilitation plan must therefore answer two questions at the same time: what the reconstruction can tolerate and what the patient needs to regain. The first is defined by morphology, reduction, fixation, bone and soft-tissue biology, and any associated repair; the second includes motion, strength, gait, self-care, work, recreation, and confidence. Separating these questions helps avoid both reflexive, prolonged restriction and unsupported acceleration.

2. Methods

This narrative review used a targeted, iterative literature search covering publications dated 1 January 2020 to 2 September 2026. PubMed/MEDLINE was the principal database. Two reproducible PubMed verification searches were run for this revision on 7 October 2026 while retaining the original eligibility cutoff. The first combined tibial plateau or proximal tibial fracture terms with motion, loading, exercise, strength, gait, balance, and stiffness terms; the second covered function, pain, participation, quality of life, and patient experience. The exact executable strings, fields, date filters, and retrieval counts are reported in Supplementary Appendix S2. These are documented revision searches rather than a retrospectively asserted verbatim record of the original iterative queries.

Full-length English-language adult studies were eligible when they addressed operative tibial plateau fractures, closely defined proximal tibial fractures, or mixed fracture populations with clinically relevant tibial plateau data. Case reports, conference abstracts, retracted publications, studies confined to nonoperative care, and purely technical reports without meaningful rehabilitation relevance

were excluded. Clinical eligibility was assessed from the reports rather than imposed through age, human-study, or study-design search filters. Records were reconciled by DOI and title. Either an eligible issue date or a verified online-first publication date within the specified interval established date eligibility; a later issue date alone did not exclude an already published article.

Publisher records were used for targeted citation follow-up and bibliographic verification, not as a separately indexed database. Candidate articles were traced by exact title or DOI from PubMed records, the included reviews, and reference lists, and the corresponding publisher landing pages were checked for the version of record, journal details, and publication dates. Supplementary Appendix S2 distinguishes this process from an exhaustive search of publisher websites. The synthesis retained 46 publications: 41 original research reports and five reviews. This is a publication count, not a count of independent participant cohorts. Potentially overlapping reports were interpreted together rather than as independent replication.

The evidence map recorded design, population and fracture focus, rehabilitation domain, role in the synthesis, principal finding, and main limitation for each publication (Supplementary **Table S1**). Randomized and prospective comparative evidence received greater interpretive weight than retrospective, cross-sectional, or descriptive evidence. Review articles principally provided context. Safety outcomes included loss of reduction, collapse, fixation failure, delayed union or non-union, reoperation, wound problems, and symptom deterioration; clinical outcomes included motion, pain, strength, gait, balance, daily activities, work, sport, quality of life, and patient-reported function. Selection and extraction were performed by a single reviewer; the review was not prospectively registered and did not use a formal risk-of-bias or GRADE assessment.

3. Evidence Synthesis

3.1. Early Motion and Postoperative Stiffness

Restoration of knee motion is a central early objective when fixation and soft tissues permit. In a retrospective, single-centre cohort of 220 adults, 57 patients (25.9%) had knee ROM below 125 degrees at one year. Orthopaedic polytrauma, Schatzker V-VI fractures, and ORIF rather than closed reduction with minimally invasive fixation were independently associated with reduced ROM [11]. These associations do not establish causation, and the incidence should not be interpreted as a universal rate. The findings support surveillance of both flexion and extension, especially after complex injury.

Motion and axial loading should be treated as related but distinct decisions. A cohort evaluating a combined surgical and rehabilitation strategy incorporated unrestricted postoperative motion and early weight-bearing as tolerated [2]. Because rehabilitation was embedded within the surgical strategy, this does not establish the independent effect of motion or a universal timetable. Within the restrictions of the reconstruction and any associated repair, this review proposes

restoration of extension, progressive flexion, quadriceps activation, swelling control, and surveillance for a plateau or reversal in progress.

Persistent restriction warrants reassessment for pain-related inhibition, infection, mechanical obstruction, adherence difficulties, or established arthrofibrosis rather than indefinite continuation of an ineffective programme. In 28 patients with arthrofibrosis who had failed nonsurgical treatment, arthroscopic lysis of adhesions with manipulation improved ROM by a mean of 47.6 degrees at 12 weeks [12]. This uncontrolled treatment series supports an option for established stiffness, not a routine postoperative intervention or proof of a preventive protocol.

3.2. Weight-Bearing, Fixation, and Fracture Context

Weight-bearing practice remains variable internationally [13]. A mixed-fracture prospective cohort supported permissive loading [14], while a comparative cohort found earlier progression feasible after selected tibial plateau fixation [15]. Two randomized reports from the same centre describe clinical and gait outcomes after immediate weight-bearing as tolerated in selected Schatzker I-IV fractures [16], [17]. They are treated here as potentially overlapping reports, not independent confirmation: both describe a recruitment pool of 106 patients and ethics approval 17200756, but the clinical report analysed 45 completers and the gait report 29. The exact participant overlap cannot be established from the available publications. Their registration details are also inconsistent: Ibrahim, Moustafa, *et al.* (2025) [16] cite NCT05502679, whereas the NCT03785457 identifier in Ibrahim, Brismée, *et al.* (2025) [17] resolves to an unrelated low-back-pain trial. Neither this discrepancy nor the different analysed sample sizes establishes cohort independence. The clinical report found improved clinical outcomes without a significant overall radiographic difference; the gait report contributes complementary functional outcomes.

These findings do not justify universal acceleration. In older patients, clinical outcomes were comparable, but early loading was associated with greater loss of condylar-widening correction, supporting closer imaging surveillance [18]. A recent meta-analysis supports the overall direction toward earlier loading but included heterogeneous tibial-fracture evidence, limiting tibial plateau-specific certainty [19]. **Table 1** summarizes the most decision-relevant quantitative findings; the implications of operative constructs are considered separately below.

The studies summarized here do not establish that rehabilitation accelerates union independently of fracture biology and fixation. Progression is defensible when it provides an appropriate mechanical and functional stimulus without loss of alignment, articular support, or hardware integrity. Given the limitations of the loading evidence above, this review proposes greater caution for Schatzker V-VI fractures, fracture-dislocations, major comminution, poor subchondral support, associated repair, or uncertain fixation. Permitted motion and muscle activation may progress while axial loading remains protected and individualized.

Table 1. Decision-relevant findings from original rehabilitation and outcome studies.

Study	Design/population	Quantified or clinically relevant findings	Interpretation and limitation
J. Li <i>et al.</i> (2021) [11]	Retrospective cohort; 220 adults	25.9% had knee ROM below 125 degrees at one year.	Supports early stiffness surveillance; cannot establish causation.
Palke <i>et al.</i> (2022) [20]	Randomized mixed-fracture trial	Dynamic Gait Index changes favored anti-gravity treadmill rehabilitation.	Mixed population and attrition; no significant primary PROM difference
Kadam <i>et al.</i> (2024) [21]	Pilot RCT; proximal tibial fractures	Most 12-week outcomes favored earlier loading plus physiotherapy.	Small sample and broader fracture population
Sudo <i>et al.</i> (2024) [18]	Propensity-matched elderly cohort	Similar clinical outcomes; greater loss of condylar-widening correction with early loading.	Supports closer imaging in vulnerable patients.
Ibrahim, Moustafa, <i>et al.</i> (2025) [16]	Randomized clinical report; Schatzker I-IV; 45 completed	Immediate WBAT improved clinical outcomes without significant overall radiographic differences.	Potential overlap with the gait report; interpret together, not as an independent replication.
Ibrahim, Brismée, <i>et al.</i> (2025) [17]	Randomized gait report; Schatzker I-IV; 29 completers	Better step/stride measures, walking velocity, and POMA gait/balance scores at three months	Participant overlap unresolved; registration inconsistency; POMA scores are not observed fall counts.
Sun <i>et al.</i> (2026) [22]	Cross-sectional; 64 patients	The lower-function group showed whole-limb and cortical-control differences.	Mechanistic associations, not treatment effects
Elseo and Larsen (2021) [23]	Prospective cohort; 56 lateral fractures	KOOS outcomes improved significantly between one and three years.	Recovery may continue well beyond union; no rehabilitation randomization.
O'Neill <i>et al.</i> (2025) [24]	Retrospective cohort; 207 patients	Return to work: 39% with infection versus 81% without infection	Complications may dominate recovery; observational association
Resch <i>et al.</i> (2025) [25]	Observational cohort	Operative subgroup returned to work earlier than the sport subgroup.	Useful for counseling, not fixed deadlines.
Vaartjes <i>et al.</i> (2025) [26]	Multicenter cohort; 1,101 patients	Daily function was often recovered while sport remained below reference values.	Mixed treatment and no individual pre-injury baseline
Du <i>et al.</i> (2026) [27]	Cross-sectional controlled study	Kinesiophobia partly mediated selected BMI-biomechanical associations.	Does not prove that psychological treatment changes biomechanics.
Fändriks <i>et al.</i> (2026) [28]	Qualitative study	Information, expectations, continuity, confidence, and adaptation shaped recovery.	Published online 25 February 2026; qualitative experience evidence, not a treatment effect

Note: The two Ibrahim reports are presented separately by outcome but are not assumed to provide independent patient samples. RCT, randomized controlled trial; ROM, range of motion; WBAT, weight-bearing as tolerated; POMA, Performance Oriented Mobility Assessment.

Loading terminology remains inconsistent: immediate weight-bearing as tolerated, early partial loading, permissive loading, and progression earlier than a local standard do not represent identical exposures [13]. Studies and clinical records should, therefore, state the postoperative day or week at initiation, the permitted load, use of assistive devices, progression criteria, adherence, and the load actually achieved. This precision is essential when results are compared or translated into practice.

The operative construct modifies the rehabilitation environment. Comparative studies of circular fixation, open reduction and internal fixation, locking-plate constructs, and arthroscopic-assisted fixation show different loading pathways

and early functional milestones [29]-[31]. These studies do not prove that one technique creates a universal rehabilitation schedule. They reinforce the need to base progression on the achieved reduction, subchondral support, fixation purchase, associated procedures, and soft-tissue condition rather than the name of the operation alone.

3.3. Exercise, Strength, Gait, Balance, and Pain

Direct evidence for specific exercise dosage remains limited. Anti-gravity treadmill rehabilitation improved the change in the Dynamic Gait Index in a randomized mixed ankle and tibial plateau cohort, although the primary patient-reported outcomes did not differ significantly between groups and attrition restricted inference [20]. Structured rehabilitation may benefit osteoporotic patients, but current evidence is retrospective [32]. A prospective lateral-fracture cohort documented continued improvement in knee-related outcomes between one and three years, illustrating that recovery may extend well beyond union [23].

Later rehabilitation should address the whole limb rather than isolated knee motion. A two-year longitudinal study documented persistent abnormalities in lower-limb kinematics, including reduced ankle plantarflexion compared with a healthy reference [33]. Gait analysis after severe tibial plateau fractures also identified residual walking impairments [34]. These observations support assessment of the hip, knee, and ankle together, but do not determine the optimal exercise dose or prove the effectiveness of any one strengthening program.

Pain control should permit sleep, movement, muscle activation, and safe loading while minimizing medication-related impairment. A retrospective analgesia study linked lower pain and opioid use with earlier functional exercise [35]. This association does not establish a causal rehabilitation benefit. An unexpected increase in symptoms should be assessed using the safety-monitoring approach in Section 4 rather than being managed simply by increasing exercise or analgesia.

Loading should be integrated with active rehabilitation. A pilot randomized trial combining earlier weight-bearing with conventional physiotherapy reported better short-term pain, motion, function, and quality-of-life outcomes, while a trial in selected Schatzker I-IV fractures paired immediate weight-bearing with structured exercise and found better clinical recovery without a significant overall radiographic disadvantage [16] [21]. Small samples and selected populations limit precision, but these findings argue against treating weight-bearing as an isolated instruction.

Persistent limitation should not be attributed to muscle loss alone. Cross-sectional neuromuscular data identified differences in co-contraction, whole-limb coordination, and central motor control between higher- and lower-functioning patients [22]. These are mechanistic associations, not treatment effects. Within surgical restrictions, the proposed exercise programme aims to preserve quadriceps recruitment and hip, ankle, calf, and contralateral limb capacity. Later treat-

ment should progress to closed-chain strength, weight acceptance, stair control, ankle push-off, endurance, and multidirectional tasks; the optimal dose remains uncertain.

Walking independence is an important milestone but not evidence of normalized gait. Functional assessment identified altered loading, particularly on stairs and during outdoor walking [36]. Gait abnormalities have also been studied after circular fixation of high-grade Schatzker VI injuries [37], while a prospective lateral-fracture cohort evaluated gait recovery over three years [38]. Assessment should therefore extend beyond level walking to stance-time symmetry, step and stride length, knee excursion, hip stability, ankle push-off, balance, stairs, and confidence. These domains inform the proposed retraining framework rather than constituting a validated test battery.

3.4. Patient-Centered Recovery and Independence

Bird *et al.* (2023) [39] found that tibial plateau fracture-dislocation was associated with more arterial injury, acute ligament repair, late instability, and subsequent ligament reconstruction. Mean knee flexion was 5 degrees lower, but pain, overall functional scores, and return to sport were similar to fractures without dislocation at follow-up. Associated injury burden should therefore inform assessment without assuming uniformly poorer function. Long-term outcomes are also heterogeneous: poor function despite low arthroplasty conversion was reported in one cohort [40], whereas another documented favorable long-term survivorship and functional outcomes [41]. Arthroplasty avoidance alone is consequently an incomplete rehabilitation endpoint.

Long-term mixed-methods evidence identified persistent disability and unmet needs in self-care, physiotherapy access, and post-discharge support [42]. In response to these needs, this review proposes explicit assessment of transfers, toileting, bathing, dressing, medication and brace management, meal preparation, stairs or home entry, household walking, community access, and the ability to seek help. This is a practical independence checklist, not a validated tibial plateau fracture-specific scale. Older adults and people living alone may need particular attention to available assistance and the home environment.

Participation recovers in stages. In one cohort, surgically treated employed patients returned to work after a mean of 11.3 ± 9.5 weeks, whereas return to sport occurred after 22.1 ± 17.9 weeks and frequently involved lower-impact activity [25]. A multicentre cohort of 1101 patients similarly found that daily function often recovered while sport remained below population reference values [26]. A surgical follow-up cohort also documented effects on activity and quality of life [43]. These estimates support counselling but are not fixed deadlines for an individual patient.

Patient-reported measures add information not captured by radiographs or isolated physical tests. KOOS has demonstrated relevance, reliability, and responsiveness after surgically treated lateral tibial plateau fracture [44]. Outcome

cohorts document persistent effects on activity and quality of life [45] [46]. Cross-sectional data link kinesiophobia with selected biomechanical and body mass index measures, without establishing causation [27]. Qualitative evidence highlights expectations, information, confidence, and continuity of care [28]. These findings support assessing psychological and practical barriers alongside physical capacity.

4. Criterion-Based Rehabilitation Framework

After No single timetable is validated for every operatively treated tibial plateau fracture. The proposed algorithm begins with fracture morphology, reduction, fixation stability, bone quality, soft tissues, associated procedures, and surgeon restrictions, then uses repeated clinical and radiographic reassessment to control motion and loading decisions (Figure 1). It is a decision aid rather than a prescription.

Table 2 organizes care into protection and early motion, controlled loading, functional strengthening and gait, higher-level function, and return to work or sport. Advancement depends on maintained reconstruction, the symptom response defined below, movement quality, task performance, and growing self-management capacity rather than elapsed time alone.

Table 2. Criterion-based postoperative rehabilitation phases.

Phase	Focus	Key content	Progression and independence criteria	Narrative confidence
1	Protection and early motion	Wound/symptom control; permitted ROM; quadriceps, hip, ankle, and calf activation; transfers	Stable wound; no warning signs; safe transfers; understands restrictions and the home plan	Low-moderate
2	Controlled loading	Progress ROM and whole-limb strength; begin surgeon/study-defined loading; household activity.	Return to pre-session symptoms by the next morning; no worsening swelling, ROM, gait, or task tolerance; maintained reconstruction; increasing self-care	Moderate
3	Strength and gait	Closed-chain strength; weight acceptance; gait symmetry; balance; stairs; endurance	Safe limb control; improving gait; acceptable next-day response; no new imaging concerns; community mobility	Low-moderate
4	Higher-level function	Dynamic balance; uneven surfaces; multidirectional control; occupational simulation; impact preparation	Stable symptoms after increased demand; adequate control and endurance; independent community participation	Low
5	Return to work/sport	Demand-specific testing and graded reintegration	Acceptable motion, strength, gait, balance, endurance, task tolerance, confidence, imaging, and clearance	Low-moderate

Note: Phases are criterion-based, not fixed postoperative dates. The symptom-response rule is defined in this section and is an unvalidated clinical convention. Narrative confidence is not a formal GRADE rating.

Radiographic maintenance and complications were assessed in comparative early-loading studies [15] [18]. Within the proposed framework, an acceptable symptom trajectory means that any increase in familiar activity-related discomfort is transient and returns to the individual pre-session level by the following morning, approximately 24 hours after the loading change. Swelling or effusion,

knee motion, gait quality, sleep, and ability to complete usual permitted tasks should be stable or improving, without an increased need for rescue analgesia. This next-day rule is a pragmatic monitoring convention proposed for the pathway; it is not a validated tibial plateau fracture-specific threshold or evidence that symptom tolerance alone establishes mechanical safety.

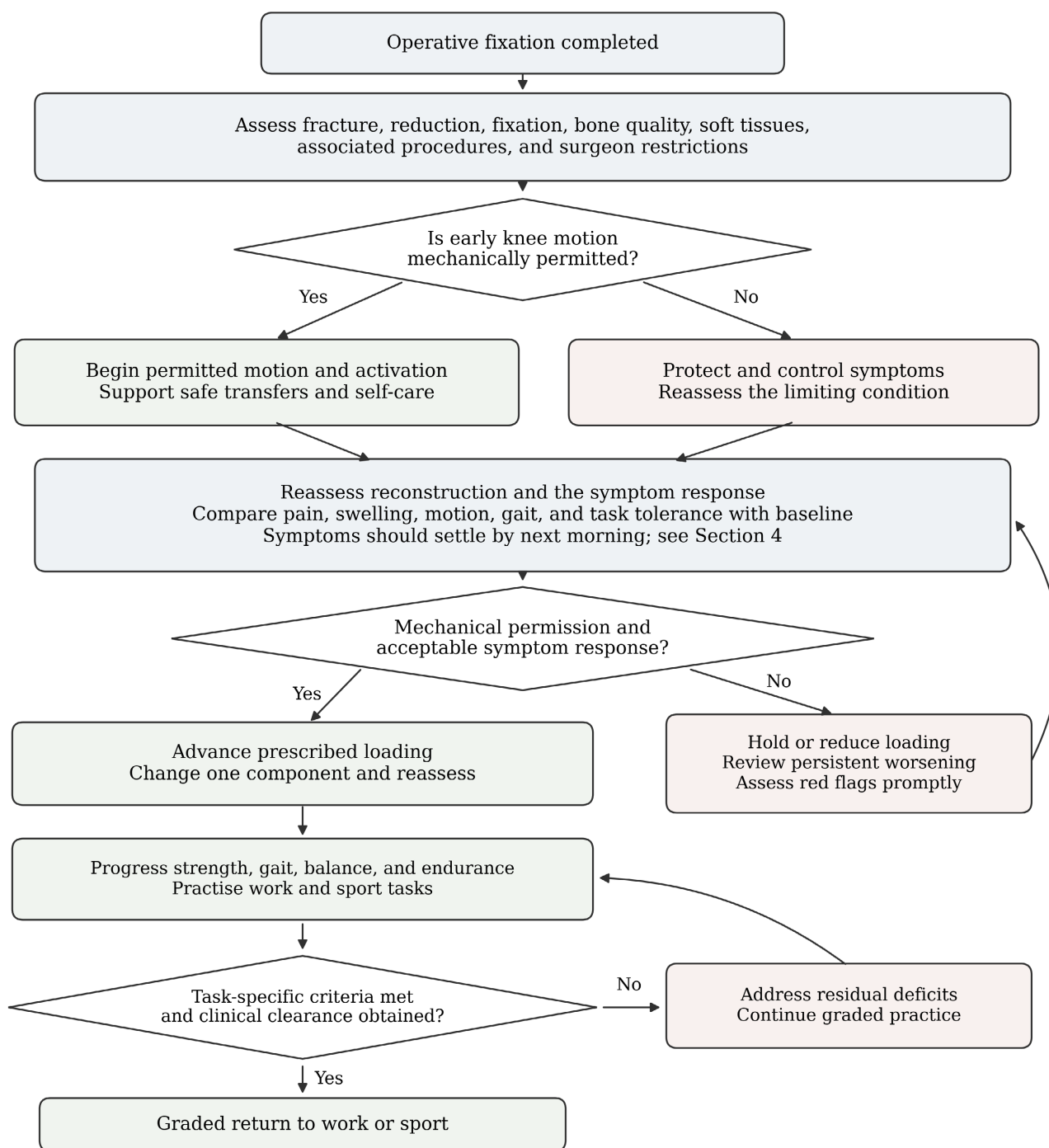


Figure 1. Evidence-informed criterion-based rehabilitation decision algorithm. Symptom response is assessed against the individual baseline and the following morning as defined in Section 4. The pathway and symptom rule have not been prospectively validated. Mechanical restrictions and indicated imaging take priority.

Before increasing loading, the clinician and patient should record resting and activity pain on the same scale, the location and character of pain, swelling or effusion, extension and flexion, gait with the prescribed aid, and current task tolerance. Recheck the response during or after the session and the next morning. If symptoms have returned to baseline, function is maintained, and the surgeon confirms that the reconstruction permits progression, increase one component of loading at a time and reassess. A persistent increase in pain or swelling, loss of motion, worsening limp, disturbed sleep, or declining task tolerance should prompt a return to the last tolerated dose and clinical review before further progression. No universal pain-score increase, load percentage, or weekly increment is supported by the included evidence.

Progression should stop and prompt timely surgical or medical assessment for wound drainage or spreading erythema, fever, rapidly increasing pain or swelling, new mechanical symptoms, sudden loss of function, or concern about alignment, articular subsidence, condylar widening, or hardware integrity. A reassuring symptom response does not override prescribed restrictions or indicated imaging. These safety prompts are clinical reassessment triggers, not a validated prediction rule.

During protection, priorities remain permitted motion, quadriceps activation, preservation of hip and ankle capacity, safe transfers, and understanding of restrictions. Once mechanically permitted, loading is tolerated, rehabilitation progresses through strength, gait, balance, stairs, endurance, and task-specific practice. Higher-level work or sport requires demand-matched assessment and clinical clearance, rather than elapsed time or union alone.

The independence checklist in Section 3.4 should be recorded alongside physical performance, specifying whether each task is completed independently, with an aid, or with another person's assistance. Home support, confidence, and the ability to follow restrictions should inform discharge planning. Independent walking should not replace the assessment of self-care, community mobility, or higher-level participation. These practical milestones complement the clinical and radiographic criteria rather than establish universal clearance thresholds.

5. Discussion

The evidence supports a conditional shift from routine restriction toward criterion-based progression. Comparative loading cohorts support considering earlier progression, although their observational designs do not eliminate selection bias [14] [15]. Progressive rehabilitation is not synonymous with aggressive rehabilitation: it advances only after mechanical and clinical checks. The potential costs of restriction, including stiffness, muscle loss, gait dysfunction, dependence, and fear, must be weighed against protection of the reconstruction. The clinically important question is which patient can tolerate which dose of motion and loading under which fixation conditions.

The strongest loading evidence applies to selected, mechanically stable frac-

tures. The clinical and gait reports discussed in Section 3.2 describe improvements in clinical scores and walking or balance measures, but their uncertain participant overlap prevents treating them as two independent replications [16] [17]. Safety estimates remain imprecise for comminuted bicondylar injuries. Schatzker classification describes morphology but cannot replace assessment of reduction, subchondral support, construct stability, bone quality, soft tissues, associated repair, symptoms, and serial imaging. The condylar-widening finding in an elderly cohort reinforces this caution [18]. Age should prompt assessment of frailty, fall risk, adherence, home support, and fixation purchase rather than determine the schedule alone.

Objective functional assessment and patient-reported outcome studies support evaluating more than level walking or radiographic success [36] [45]. On this basis, the review proposes that a successful outcome should combine maintained reconstruction with recovery of motion, whole-limb strength, gait, balance, independence, work capacity, recreation, and confidence. Quantified functional testing and patient-reported outcomes should complement one another before discharge or higher-level return; neither provides a universal clearance threshold.

Progressive and restrictive rehabilitation are not binary protocols. In the proposed framework, motion, muscle activation, axial loading, gait practice, and higher-level activity can advance at different rates. A patient may begin permitted knee motion and proximal and distal muscle exercises while axial loading remains protected. This domain-based approach aims to preserve the safety rationale of restriction while addressing stiffness, muscle loss, imbalance, falls risk, and dependence. Its effectiveness as a complete pathway requires prospective testing.

Complications can outweigh the effect of the planned schedule. In a cohort of 207 patients, return to work was 39% among those with infection and 81% among those without infection [24]. Outcomes should therefore combine radiographic maintenance, wound status, adverse events, symptoms, motion, lower-limb strength, gait, balance, independence in activities of daily living, patient-reported function, work and sport capacity, and confidence. Where validated universal thresholds are unavailable, documented trajectories and task-specific performance are preferable to invented cut-offs.

6. Evidence Gaps and Future Research

Research should prioritize phenotype-stratified multicenter trials, objective measurement of actual loading exposure, reproducible exercise dosage, and validated readiness criteria. Trials should report fracture morphology, fixation construct, bone quality, associated procedures, exact initiation and progression of loading, adherence, adverse radiographic events, and patient-centered outcomes.

Exercise trials are particularly needed for strengthening, neuromuscular and balance training, aquatic therapy, graded exposure, and return to running or sport. Longitudinal work should determine when union, independent walking, work capacity, and participation diverge. Research should also test whether psy-

chological screening, shared goals, continuity of care, and structured post-discharge support improve meaningful recovery. Criteria for discharge, heavy work, running, and sport require validation.

7. Limitations

The targeted narrative design and the review procedures described in Section 2 allow relevant studies to be missed and introduce selection and interpretive bias; publication bias was not assessed. Fracture morphology, fixation, loading definitions, follow-up, and outcome measures varied, and mixed fracture populations often lacked separate tibial plateau estimates. Uncertain overlap between some reports further limits the amount of independent evidence. These constraints prevent precise causal or subgroup conclusions and make the absence of a statistically significant harm signal insufficient to establish safety for all patients.

Most evidence concerns weight-bearing or general recovery rather than reproducible exercise prescriptions. Evidence remains particularly limited for Schatzker V-VI fractures, severe osteoporosis, fracture-dislocation, and associated soft-tissue repair. The complete pathway, including its next-day symptom rule and return criteria, has not been prospectively validated and should not be treated as a universal protocol.

8. Clinical Implications

The clinical priorities derived from this synthesis are to begin permitted motion and muscle activation early while linking load progression to fracture and fixation stability, symptoms, examination, and indicated imaging. Once loading is allowed, assess strength, gait, balance, endurance, confidence, activities of daily living, and demand-specific work or sport performance. Coordinate restrictions and progression criteria among the surgeon, therapist, and patient. These are evidence-informed recommendations rather than a validated universal protocol.

When progress stalls, clinicians should reassess quadriceps and whole-limb weakness, hip and ankle compensation, gait asymmetry, balance, pain, mechanical symptoms, fear of movement, adherence, and social barriers. Return decisions should match the actual demands of self-care, community mobility, sedentary or manual work, recreation, and sport. Qualitative findings highlight the importance patients attach to information and continuity of care [28]. This review therefore recommends a written plan identifying permitted motion and loading, the next review point, warning signs, the responsible clinician, and the objective or functional findings required before advancement.

9. Conclusion and Perspective

Routine prolonged immobilization and non-weight-bearing should not be automatic after operative tibial plateau fracture treatment. Permitted early motion is reasonable, and earlier loading has improved clinical or gait outcomes in selected stable fractures without significant overall radiographic differences. These find-

ings do not establish safety for every fracture or justify universal acceleration. Rehabilitation should protect biology and fixation while addressing stiffness, weakness, gait deterioration, fall risk, dependence, and fear. The most defensible approach is individualized, criterion-based, and continued until reconstruction is maintained and meaningful physical, psychological, and participation goals are achieved.

Declaration

The authors declare that no generative AI or AI-assisted technologies were used in the design, data collection, analysis, interpretation, or writing of this manuscript. All content, including text, figures, and tables, was generated and reviewed solely by the authors.

Author Contributions

Daniel Louis Ndika: Conceptualization, data curation, formal analysis, writing original draft, writing review & editing. Amani Pelesi Fungo: Conceptualization, data curation, formal analysis, writing review & editing. Namuunza Moonga Lyambai: Data curation, formal analysis, writing review & editing. Sariluci Coral Marquez: Data curation, resources, writing review & editing. Hamidu Saidu Ibrahim: Data curation, formal analysis, writing review & editing. Qifang He: Conceptualization, supervision, project administration, resources, methodology, writing review & editing. All authors approved the submitted version and agreed to be accountable for their contributions.

Conflicts of Interest

The authors declare no conflicts of interest.

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Appendix: Supplementary Table S1

Supplementary material for postoperative rehabilitation after tibial plateau fractures

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Table S1. Evidence map of 46 publications, including 41 original research reports and five reviews. Publication totals do not represent independent cohorts. The limitations are descriptive, not formal risk-of-bias ratings.

Study	Design	Population /fracture focus	Primary rehabilitation domain	Role in synthesis	Principal limitation
Callary <i>et al.</i> (2020)	Clinical cohort/management protocol	Operatively treated tibial plateau fractures	Early motion/functional progression	Supporting-direct	Rehabilitation was embedded within a surgical management strategy rather than being isolated as an intervention.
Iliopoulos <i>et al.</i> (2020)	Observational gait-analysis cohort	Severe tibial plateau fractures	Gait	Direct functional evidence	Small observational sample; no rehabilitation comparison.
Hap and Kwek (2020)	Functional outcome cohort	Surgically treated tibial plateau fractures	Work/sport/function	Supporting	Observational outcomes; rehabilitation exposure was not standardized.
Gonzalez <i>et al.</i> (2020)	Longitudinal cohort	ORIF-treated tibial plateau fractures	Long-term function	Supporting	Cannot identify which rehabilitation components explain the improvement.
Ochen <i>et al.</i> (2020)	Long-term observational cohort	Bicondylar tibial plateau fractures after ORIF	Long-term function	Supporting	Complex-fracture cohort; observational design.
Bennett <i>et al.</i> (2021)	2-year longitudinal kinematic study	Postoperative tibial plateau fractures	Gait/whole-limb kinematics	Direct functional evidence	No randomized rehabilitation intervention.
J. Li <i>et al.</i> (2021)	Retrospective cohort	220 adults after surgery for closed tibial plateau fractures	ROM/stiffness risk	Direct prognostic evidence	Single-center retrospective design.
Elsoe and Larsen (2021)	Prospective cohort	56 lateral tibial plateau fractures after screw fixation	Strength/gait/PROMs trajectory	Supporting-direct	Single-center lateral-fracture cohort. Reports describe a 56-patient lateral-fracture cohort and are not assumed to be independent cohorts.
Palke <i>et al.</i> (2022)	RCT	Mixed ankle and tibial plateau fractures	Anti-gravity treadmill/gait	Direct intervention evidence	Mixed fracture population and attrition.
H.-F. Li <i>et al.</i> (2022)	Observational/comparative surgical cohort	Complex tibial plateau fractures	Loading/functional recovery	Supporting	Surgical construct study rather than an isolated rehabilitation trial.
Middleton <i>et al.</i> (2022)	Retrospective intervention cohort	Postoperative tibial plateau arthrofibrosis	Stiffness treatment	Direct complication-treatment evidence	Applies to established arthrofibrosis, not to routine rehabilitation.
Beisemann <i>et al.</i> (2022)	Retrospective cohort	Operatively treated tibial plateau fractures	Reduction quality/function	Supporting prognostic evidence	Association cannot establish a rehabilitation response.
Bagherifard <i>et al.</i> (2023)	Observational outcomes study	Surgically treated tibial plateau fractures	Function/quality of life	Supporting	No standardized rehabilitation intervention exists.
Gahr, Mittlmeier, <i>et al.</i> (2023)	Retrospective functional-assessment cohort	Displaced, surgically treated tibial plateau fractures	Functional performance	Supporting-direct	Observational design.
Larsen and Elsoe (2023)	Prospective 3-year cohort	Lateral tibial plateau fractures	Gait recovery	Direct functional evidence	Single-center cohort; no rehabilitation randomization. Reports describe a 56-patient lateral-fracture cohort and are not assumed to be independent cohorts.

Continued

Wang <i>et al.</i> (2023)	Observational cohort	Schatzker VI with associated proximal fibular/posterolateral injury	Early functional recovery	Supporting prognostic evidence	Highly selected complex-fracture subgroup.
Bird <i>et al.</i> (2023)	Comparative cohort	Knee fracture versus fracture-dislocation patterns	Functional status	Supporting prognostic evidence	Not designed to test rehabilitation.
Heiman <i>et al.</i> (2024)	Comparative cohort	Operatively treated tibial plateau fractures	Earlier vs. standard loading	Direct loading evidence	Nonrandomized comparative design.
Kadam <i>et al.</i> (2024)	Pilot RCT	Type I-III surgically treated proximal tibial fractures	Earlier loading + physiotherapy	Direct intervention evidence	Small pilot sample; broader proximal tibial population.
Sudo <i>et al.</i> (2024)	Multicenter propensity-matched cohort	Elderly internally fixed tibial plateau fractures	Earlier vs. delayed loading	Direct loading evidence	Observational, despite matching; elderly population.
Kalmet <i>et al.</i> (2024)	Prospective comparative multicenter cohort	106 peri- and intra-articular lower-extremity fractures, including 44 tibial plateau fractures	Permissive vs. restricted weight-bearing	Supporting-direct loading evidence	Mixed fracture population; tibial plateau outcomes were not reported separately.
Neidlein <i>et al.</i> (2024)	Observational PROMs cohort	Tibial plateau fractures	PROMs/activity	Supporting	Patient-reported outcomes without standardized rehabilitation exposure.
Traerup <i>et al.</i> (2024)	Measurement-property study	Surgically treated lateral tibial plateau fractures	KOOS measurement	Supporting methodology	Evaluates outcome measurement, not the treatment effect.
Kraml <i>et al.</i> (2024)	Long-term cohort	Tibial plateau fractures	Function/arthroplasty conversion	Supporting	Rehabilitation-specific exposures are not isolated.
O'Neill <i>et al.</i> (2025)	Retrospective prognostic cohort	Operatively treated tibial plateau fractures with or without infection	Complications/return to work	Supporting prognostic evidence	Infection-related confounding; nonrandomized.
Zhu <i>et al.</i> (2025)	Retrospective cohort	Osteoporotic tibial plateau fractures	Systematic postoperative rehabilitation	Direct-supporting intervention evidence	Retrospective design; protocol details/generalizability are limited.
Ibrahim, Moustafa, <i>et al.</i> (2025)	Randomized clinical report	Schatzker I-IV; 45 completers; recruitment pool 106	Immediate WBAT + exercise	Clinical outcomes, interpreted jointly with the gait report	Potential participant overlap with Ibrahim, Brismée, <i>et al.</i> (2025); exact linkage is unavailable. Clinical registration NCT05502679.
Ibrahim, Brismée, <i>et al.</i> (2025)	Randomized gait report	Schatzker I-IV; 29 completers; recruitment pool 106	Immediate loading/gait/balance	Complementary gait outcomes; no independent replication is assumed	Potential overlap with the clinical report; published NCT03785457 is inconsistent with the registry. POMA scores, not observed falls.
Granlund and von Keudell (2025)	International surgeon survey	Orthopaedic trauma surgeons	Loading practice variation	Supporting practice evidence	Reports clinician practice, not patient outcomes.
Resch <i>et al.</i> (2025)	Observational cohort	Mixed treatment; operative subgroup available	Return to work/sport	Supporting participation evidence	Not a randomized rehabilitation study.
Vaartjes <i>et al.</i> (2025)	Multicenter cohort	1,101 patients; mixed treatment	Daily activity/sports	Supporting participation evidence	No individual pre-injury outcome baseline; mixed treatment.
Höller <i>et al.</i> (2025)	Surgical follow-up cohort	Surgically treated tibial plateau fractures	Work/sport/quality of life	Supporting participation evidence	Questionnaire response and observational design.

Continued

Arsoy <i>et al.</i> (2025)	Long-term observational cohort	170 operatively treated tibial plateau fractures (109 unicondylar, 61 bicondylar)	Long-term function/arthroplasty survivorship	Supporting prognostic evidence	Observational design; rehabilitation exposure was not isolated.
Chhabu <i>et al.</i> (2026)	Prospective randomized comparative study	Complex tibial plateau fractures	Fixation strategy/loading pathway	Supporting-direct	The primary comparison is the fixation method rather than the rehabilitation protocol.
Tian <i>et al.</i> (2026)	Retrospective comparative cohort	Arthroscopic-assisted vs. conventional ORIF	Ambulation/knee flexion	Supporting	Surgical comparison; rehabilitation was not randomized.
Song and Su (2026)	Retrospective cohort	ORIF-treated tibial plateau fractures	Pain/opioid use/early exercise	Direct-supporting	Retrospective analgesia comparison.
Sun <i>et al.</i> (2026)	Cross-sectional study	64 postoperative tibial plateau fracture patients	Neuromuscular recovery	Direct mechanistic evidence	Cross-sectional; cannot establish treatment effects.
Du <i>et al.</i> (2026)	Cross-sectional controlled mediation study	60 postoperative patients plus 20 controls	Kinesiophobia/gait biomechanics	Direct patient-centered evidence	Cross-sectional mediation; no intervention effect.
Skouras <i>et al.</i> (2026)	3D gait-analysis study	High-grade Schatzker VI after circular fixation	Gait biomechanics	Direct functional evidence	Highly selected fracture/fixation subgroups.
Fändriks <i>et al.</i> (2026)	Qualitative study	Working-age patients during the first 2 years after TPF	Patient experience	Direct patient-centered evidence	Published online 25 February 2026; issue date 31 December 2026. Qualitative findings do not estimate treatment effects.
van der Gaast <i>et al.</i> (2026)	Mixed-methods study	46 participants; mixed treatment; 18 qualitative interviews; 5–10-year follow-up	Long-term PROMs/quality of life/patient experience	Supporting long-term and patient-centered evidence	28% response rate; small sample; mixed treatment and recall bias.
Iliopoulos and Galanis (2020)	Systematic review	Tibial plateau fracture fixation rehabilitation	Physiotherapy/ROM/immobilization/loading	Review evidence	Underlying literature is sparse and heterogeneous.
Canton <i>et al.</i> (2022)	Systematic review	ORIF-treated tibial plateau fractures	Earlier weight-bearing	Review evidence	Included studies were heterogeneous and mostly nonrandomized.
Gahr, Kopf, and Pauly (2023)	Current-concepts review	Proximal tibial fractures	Management context	Supporting review	Broader proximal tibial management focus, not rehabilitation-specific.
Chana-Rodríguez <i>et al.</i> (2025)	Current-concepts review	Tibial plateau fracture management	Management context	Supporting review	Broad management review rather than direct rehabilitation evidence.
Elsenosy <i>et al.</i> (2025)	Systematic review/meta-analysis	Heterogeneous tibial fracture evidence, including TPF	Earlier vs. delayed loading	Review evidence	Mixed tibial fracture populations reduce TPF-specific certainty.

Abbreviations: TPF, tibial plateau fracture; RCT, randomized controlled trial; ROM, range of motion; PROM, patient-reported outcome measure; KOOS, Knee Injury and Osteoarthritis Outcome Score; POMA, Performance-Oriented Mobility Assessment.

Supplementary Appendix S2

Search documentation and source verification

The following searches were executed in PubMed via the NCBI E-utilities interface on 7 October 2026 (Asia/Shanghai). They document verification during revision and retain the original eligibility window of 1 January 2020 through 2 September 2026. They are not represented as archived verbatim logs of the original iterative search or as a new systematic review. Search-result counts are retrieval counts, not numbers screened or included. No claim of exhaustive screening of these revision results is made.

Q1 Motion loading exercise and gait

Retrieved records: 614.

((("tibial plateau"[Title/Abstract] OR "proximal tibia"[Title/Abstract] OR "proximal tibial"[Title/Abstract]) AND fracture[Title/Abstract]) AND (rehabilitation[Title/Abstract] OR physiotherap[Title/Abstract] OR "physical therapy"[Title/Abstract] OR "weight bearing"[Title/Abstract] OR "weight-bearing"[Title/Abstract] OR mobilization[Title/Abstract] OR mobilisation[Title/Abstract] OR "range of motion"[Title/Abstract] OR stiffness[Title/Abstract] OR arthrofibrosis[Title/Abstract] OR exercis[Title/Abstract] OR strength[Title/Abstract] OR gait[Title/Abstract] OR balance[Title/Abstract]) AND ((("2020/01/01"[Date - Publication] : "2026/09/02"[Date - Publication]) OR ("2020/01/01"[EPDAT] : "2026/09/02"[EPDAT])) AND english[Language])

Q2 Function participation and patient experience

Retrieved records: 1234.

((("tibial plateau"[Title/Abstract] OR "proximal tibia"[Title/Abstract] OR "proximal tibial"[Title/Abstract]) AND fracture[Title/Abstract]) AND ("return to work"[Title/Abstract] OR "return to sport"[Title/Abstract] OR "return to sports"[Title/Abstract] OR "quality of life"[Title/Abstract] OR "patient reported"[Title/Abstract] OR "patient-reported"[Title/Abstract] OR function[Title/Abstract] OR outcome[Title/Abstract] OR experience[Title/Abstract] OR kinesiphobia[Title/Abstract] OR independence[Title/Abstract] OR pain[Title/Abstract]) AND ((("2020/01/01"[Date - Publication] : "2026/09/02"[Date - Publication]) OR ("2020/01/01"[EPDAT] : "2026/09/02"[EPDAT])) AND english[Language])

The two queries returned 1381 unique PubMed identifiers after deduplication by PMID. The retained narrative evidence set comprises 46 publications. These numbers serve different purposes and are not a study-selection flow diagram.

Fields and eligibility

Title/Abstract limits terms to those indexed fields; the asterisk applies truncation. English language is an explicit filter. Date—Publication and EPDAT are combined with OR so that an online-first article can be retrieved despite a later issue date. No automated human, age, or design filters were imposed; adult status, operative relevance, full-length publication, and the remaining exclusions were assessed from article information. No separate MEDLINE-subset restriction was

applied. Either an eligible issue date or a verified electronic publication date qualified the record, with dates checked on the source record where necessary.

Publisher records and reference lists

Publisher follow-up was article-specific. Exact titles and DOIs were used to trace candidate records from PubMed, the included reviews, and reference lists. Publisher landing pages were used to check article identity, publication details, and online-first dates. Crossref publisher-deposited metadata was checked by DOI during reference normalization, and PubMed/publisher information resolved missing article numbers and date discrepancies. This was not an independent, comprehensive search across all publisher sites. Reference-list follow-up supplemented the targeted narrative selection; reports were reconciled by DOI and title rather than counted twice.

Publication date of Fändriks *et al.* (2026)

Fändriks *et al.* (2026), DOI 10.1080/17482631.2026.2636758, was published online on 25 February 2026. PubMed PMID 41738535 lists this electronic publication date separately from the 31 December 2026 issue date. The paper therefore precedes the 2 September 2026 cutoff and remains eligible. **Table 1** and **Table S1** explicitly report the online date; the publication totals remain 46 and 41 original reports plus five reviews.

<https://pubmed.ncbi.nlm.nih.gov/41738535/>

<https://doi.org/10.1080/17482631.2026.2636758>

Potential participant overlap in the Ibrahim reports

The reports by Ibrahim, Moustafa, *et al.* (2025) and Ibrahim, Brismée, *et al.* (2025) share investigators, Assiut University study setting, ethics approval 17200756, similar fracture eligibility and loading comparisons, and a stated recruitment pool of 106 patients. The analysed clinical and gait samples contain 45 and 29 completers, respectively. These similarities suggest possible overlap but do not provide individual participant linkage. The publications and available registry records cannot establish the exact overlap, so this review treats the reports as potentially related evidence and does not sum their samples or claim independent replication.

The clinical paper (Ibrahim, Moustafa, *et al.*, 2025) cites NCT05502679, a tibial plateau fracture trial at Assiut University. The gait paper (Ibrahim, Brismée, *et al.*, 2025) cites NCT03785457, which the registry identifies as a standing trunk-extension study in low back pain. This registration discrepancy cannot be used as evidence that the tibial plateau cohorts are separate. Definitive overlap would require clarification from the study authors; no such correspondence is claimed here.

<https://doi.org/10.1007/s00264-025-06443-1>

<https://doi.org/10.1016/j.jbiomech.2025.112668>

<https://clinicaltrials.gov/study/NCT05502679>

<https://clinicaltrials.gov/study/NCT03785457>