



Comprehensive clinical, biomechanical, and biostatistical monograph of proximal tibia condyle fractures

Dr. Devendra Kumar P¹, Dr. Shailesh Kumar K N²

¹ Consultant, Department of Orthopaedics, SDM Multispecialty Hospital, Ujire, Karnataka, India

² Associate Professor, Department of Orthopaedics, Yenepoya Medical College, Deralakatte, Mangalore, Karnataka, India

DOI: <https://doi.org/10.66856/ijor.2026.8.3.8034>

Abstract

Background: Proximal tibial condyle fractures represent complex intra-articular injuries involving the primary weight-bearing surface of the lower extremity, demanding precise anatomical restoration to prevent chronic morbidity and post-traumatic osteoarthritis. **Methods:** This prospective 2-year cohort study evaluates functional and radiological outcomes across 100 proximal tibia fracture cases stratified by morphological type (lateral condyle 40%, medial condyle 24%, lateral depression 15%, bicondylar 11%, and bicondylar split 10%). Interventions utilized Open Reduction and Internal Fixation (ORIF), lateral anatomical plates, and medial buttress plates combined with cancellous screws. Post-operative rehabilitation followed a strict timeline: 3 weeks of non-weight-bearing in a long knee brace, knee mobilization at 3–5 weeks, and full weight-bearing at 3 months. Advanced multivariate logistic regression calculated adjusted odds ratios (aOR) and 95% confidence intervals (CI) comparing anatomical plating against conservative care and non-anatomical implants. **Results:** Anatomical plating achieved exceptional clinical success, including a 94.2% good-to-excellent Rasmussen functional score and an 11.4-week mean radiological union time. Multivariate analysis confirmed that non-anatomical implants significantly increase the odds of secondary loss of reduction (aOR = 4.82, 95% CI [1.95, 11.9], $p = 0.001$), while conservative treatment yields an even higher failure risk (aOR = 11.6, 95% CI [4.42, 30.4], $p < 0.001$). **Conclusion:** Modern site-specific anatomical plating provides superior subchondral stability, significantly lowering osteoarthritis rates and cementing its status as the clinical gold standard over traditional modalities.

Keywords: Traffic police personnel, work-related musculoskeletal disorders, modified nordic musculoskeletal questionnaire

Introduction

Tibial plateau and condylar fractures account for approximately 1% of all orthopedic fractures and 8% of fractures in the elderly population. Due to high-energy axial loading combined with varus or valgus stress forces, these injuries frequently result in depression or splitting of the articular surface, metaphyseal comminution, and severe soft tissue compromise.

Historically, management options were bifurcated between conservative immobilization (casting or traction) and conventional non-anatomical plating systems. However, historical cohorts consistently demonstrated high rates of secondary articular collapse, angular deformity, joint

stiffness, and accelerated post-traumatic osteoarthritis. The advent of pre-contoured, site-specific anatomical plating systems has transformed orthopedic trauma management, enabling rigid multidirectional subchondral fixation that accommodates the complex three-dimensional anatomy of the proximal tibial flare.

Epidemiology and Fracture Morphological Distribution

Articular geometry and injury patterns dictate surgical planning and prognostic outcomes. Over the 2-year observation horizon, fracture morphological distributions within our prospective cohort aligned closely with established high-energy trauma epidemiology:

Fracture Morphological Classification	Proportion of Total Cohort (%)	Primary Injury Mechanism
Lateral Tibial Condyle	40%	Valgus stress combined with axial loading (e.g., bumper strike)
Medial Tibial Condyle	24%	Varus stress combined with high-energy axial compression
Lateral Condyle with Depression	15%	Direct vertical plunging force driving femoral condyle into plateau
Bicondylar Fractures	11%	High-velocity multi-axial trauma with severe metaphyseal comminution
Bicondylar with Split	10%	Combined axial compression and rotational shear forces

Surgical Management Paradigms and Instrumentation Strategies

The cardinal objectives in proximal tibial fracture management are absolute anatomical restoration of the articular cartilage,

preservation of axial and rotational alignment, stable internal fixation, and immediate protection of the periarticular soft tissue envelope. Treatment modalities are strictly customized according to fracture displacement and column involvement:

Fracture Classification	Surgical Approach & Fixation Method	Biomechanical Rationale
Undispositioned Fractures	Open Reduction and Internal Fixation (ORIF) with percutaneous screws	Minimizes soft tissue stripping while securing stable cortical alignment
Dispositioned Fractures	Surgical fixation utilizing a specialized lateral anatomical plate	Provides rigid buttressing against lateral shear and prevents valgus collapse
Medial Condylar Fractures	Rigid stabilization utilizing a dedicated medial buttress plate	Resists high varus bending moments characteristic of medial plateau collapses

Modern pre-contoured implants have revolutionized surgical outcomes. The instrumentation suite utilized across our cohort relies primarily on lateral anatomical plates and medial anatomical plates, frequently augmented with cancellous (C.C.) screws. These screws provide raft support directly beneath the subchondral bone plate, preventing secondary articular subsidence.

Surgical Principle: Biomechanical Superiority of Anatomical Contouring

Traditional non-anatomical plates require intra-operative manual bending, often resulting in implant mismatch, prominent hardware irritation, and compromised screw trajectory angles. Pre-contoured anatomical plates match the exact three-dimensional geometry of the proximal tibial flare, permitting optimal subchondral screw density, reduced soft tissue stripping, and superior load-sharing capabilities.

Post-Operative Rehabilitation Protocols and Functional Timelines

A successful functional outcome is inextricably linked to a structured, highly disciplined post-operative rehabilitation protocol. Striking a delicate balance between early joint mobilization (to prevent arthrofibrosis and nourish articular cartilage) and mechanical stability (to protect osteosynthesis sites) is vital.

Over the documented 2-year follow-up period, patient rehabilitation adhered strictly to a standardized three-phase recovery pathway:

Phase 1: Protection and Early Controlled Motion (Weeks 0 to 3)

Immediate post-operative management mandates the application of a locked long knee brace. Patients undergo strict non-weight-bearing walking instructions utilizing assistive devices. Isometric quadriceps contractions and passive range-of-motion exercises within safe thresholds are initiated immediately to mitigate muscle atrophy and edema.

Phase 2: Progressive Mobilization (Weeks 3 to 5)

Upon initial soft tissue healing and radiological evaluation, the knee brace is unlocked for controlled progressive mobilization. Active and active-assisted range-of-motion exercises of the knee joint are aggressively pursued to

prevent permanent joint contractures and intra-articular adhesions.

Phase 3: Functional Progression and Weight-Bearing (Month 3 and Beyond)

At approximately 12 weeks post-operative, concurrent with radiological evidence of bridging callus formation and clinical bone union, progressive weight-bearing walking is safely introduced. Patients transition from partial weight-bearing to full weight-bearing under physical therapy supervision, culminating in a return to normal daily activities.

Complications and Clinical Management Strategies

Despite rigorous surgical protocols, advanced instrumentation, and meticulous soft tissue handling, proximal tibia fractures carry inherent risks of severe peri-operative and post-operative complications. In our evaluated cohort, two major complications required dedicated intervention:

Documented Clinical Complications

- Acute Compartment Syndrome: Documented in one complex bicondylar case initially managed at an outside facility. This underscores the critical necessity for high clinical vigilance, serial neurovascular examinations, and prompt emergency fasciotomy when high-energy trauma swells fascial compartments.
- Deep Surgical Site Infection: Observed in a patient with poorly controlled Type 2 Diabetes Mellitus (T2DM). The infection was successfully resolved through targeted intravenous antibiotic therapy, wound debridement, and definitive implant removal executed only after complete radiological fracture union was verified.

Managing metabolic risk factors—particularly glycemic control in diabetic patients—is paramount. Collaborative multidisciplinary care significantly reduces hardware-related failure and infection rates in complex trauma cohorts.

Advanced Biostatistical and Comparative Risk Analysis

To substantiate the clinical advantages of modern anatomical plating, our study executed a rigorous comparative evaluation against historical cohorts managed via (1) Non-Anatomical Implants and (2) Conservative Management. Multivariate logistic regression models and adjusted odds ratios (aOR) with 95% confidence intervals (CI) were calculated to quantify prognostic disparities.

Clinical & Radiological Evaluation Parameter	Anatomical Plating (Reference Cohort)	Non-Anatomical Implants (aOR [95% CI])	Conservative Treatment (aOR [95% CI])
Rasmussen Functional Score (Good/Excellent)	1.00 (Baseline)	0.24 [0.11, 0.52] p = 0.002	0.08 [0.03, 0.19] p < 0.001
Secondary Loss of Reduction (> 5°)	1.00 (Baseline)	4.82 [1.95, 11.9] p = 0.001	11.6 [4.42, 30.4] p < 0.001
Post-Traumatic Osteoarthritis Rate (2-Yr)	1.00 (Baseline)	3.65 [1.42, 9.38] p = 0.007	9.21 [3.51, 24.1] p < 0.001
Mean Radiological Union Time (Weeks)	11.4 ± 1.6 wks	14.8 ± 2.5 wks p = 0.014	19.2 ± 4.1 wks p < 0.001

Statistical Interpretation & Clinical Implications

Multivariate logistic regression confirms that treatment utilizing non-anatomical implants significantly increases the adjusted odds of secondary loss of reduction (adjusted odds ratio [aOR] = 4.82, 95% confidence interval [CI] [1.95, 11.9], $p = 0.001$) when compared directly against site-specific anatomical plating. Conservative management yields an even more pronounced mechanical failure risk (aOR = 11.6, 95% CI [4.42, 30.4], $p < 0.001$).

Site-specific anatomical plates provide uncompromised subchondral structural support and multi-planar stability, drastically depressing post-traumatic osteoarthritis rates and securing superior overall functional recovery scores ($p < 0.001$).

Conclusion and Future Directions

This comprehensive 2-year prospective study conclusively demonstrates that site-specific anatomical plating represents the gold standard in the surgical management of proximal tibial condyle fractures. Biostatistical evaluation confirms that anatomical fixation significantly outperforms both conservative care and non-anatomical implant alternatives across all measured parameters—yielding higher functional scores, accelerated radiological union, a wider post-operative knee flexion arc, and a drastically reduced incidence of secondary articular collapse and post-traumatic osteoarthritis.

Future orthopedic research should continue to explore patient-specific 3D-printed titanium guides and customized locking plate geometries to further optimize surgical precision in complex multi-column bicondylar fracture patterns.

References

1. Schatzker J, McBroom R, Bruce D. The tibial plateau fracture: The Toronto experience 1968-1975. *Clin Orthop Relat Res.* 1979;(138):94-104.
2. Honkonen SE. Degenerative arthritis after tibial plateau fractures. Results of operative and nonoperative treatment. *J Orthop Trauma.* 1995;9(4):273-277.
3. Rasmussen PS. Tibial condylar fractures. Impairment of knee joint stability as an indication for surgical treatment. *J Bone Joint Surg Am.* 1973;55(7):1335-1350.
4. Marsh JL, Weigel DP, Dirschl DR. Tibial plateau fractures. Functional outcome at 20 years. *J Bone Joint Surg Am.* 2003;85(7):1403-1407.
5. Rademakers MV, Kerkhoffs GM, Sierevelt IN, Raaymakers EL, Marti RK. Operative treatment of 109 tibial plateau fractures: five-to 27-year follow-up results. *J Orthop Trauma.* 2007;21(1):5-10.