

Functional and Radiological Outcomes in Adults with Proximal Tibia Fractures Treated with Intramedullary Interlocking Nail by Suprapatellar Technique: A Prospective Observational Study.

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ABSTRACT

Background:

To evaluate the functional and radiological outcomes of adults with selected proximal tibial fractures treated with intramedullary interlocking nailing using the suprapatellar technique.

Methods:

A prospective observational study was conducted in the Department of Orthopaedics at R.N.T. Medical College and Maharana Bhupal Government Hospital, Udaipur, from April 2024 to March 2025. Twenty-four adults aged 18–50 years with closed proximal tibial fractures classified as AO/OTA 41A2, 41A3, or 41B1 were included. All patients underwent intramedullary interlocking nailing through a suprapatellar approach with the knee maintained in a semi-extended position. Functional and radiological outcomes were assessed using the Knee Society Score, clinical examination, and serial radiographs.

Results:

The study included 14 males (58.3%) and 10 females (41.7%), with a mean age of 33.87 years. Road traffic accidents accounted for 20 cases (83.3%), and AO/OTA 41A2 was the most common fracture pattern, affecting 14 patients (58.3%). The mean operative time was 45.3 minutes, the mean hospital stay was 8.2 days, and the mean fracture union time was 14.5 weeks. At 3 months, 7 patients (29.1%) had excellent, 9 (37.5%) good, 5 (20.8%) fair, and 3 (12.5%) poor functional outcomes. At 6 months, 20 patients (83.3%) had excellent, 2 (8.3%) good, 1 (4.2%) fair, and 1 (4.2%) poor outcomes. Two patients developed postoperative knee stiffness, and one developed proximal screw loosening. No loss of reduction or progressive displacement was reported.

Conclusion:

Suprapatellar intramedullary interlocking nailing in the semi-extended position was associated with satisfactory functional and radiological outcomes in this small series of selected proximal tibial fractures.

Recommendation:

Larger multicentre comparative studies with standardized radiological measurements and longer follow-up are recommended to further evaluate the effectiveness and safety of the suprapatellar technique.

Keywords: Proximal tibial fracture; intramedullary nailing; suprapatellar approach; semi-extended position; Knee Society Score; fracture union.

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INTRODUCTION

Proximal tibial fractures are important injuries that may be difficult to manage because of the anatomy of the proximal tibia, the wide metaphyseal region, and the deforming forces acting on the proximal fragment. Treatment selection depends on fracture configuration, soft-tissue condition, and associated injuries.^{1,2}

Treatment options include conservative management, external fixation, plate fixation, and intramedullary fixation. Intramedullary nailing provides load-sharing fixation and may reduce the need for extensive soft-tissue dissection compared with open fixation techniques.^{3,4} However, intramedullary nailing of proximal tibial fractures can be technically demanding.

During conventional infrapatellar nailing, knee flexion may increase the deforming influence of the quadriceps mechanism and make fracture reduction difficult, particularly in proximal-third fractures.^{5,6} The semi-extended technique was developed to address some of these limitations. Tornetta and Collins described intramedullary nailing of proximal tibial fractures with the knee maintained in a semi-extended position.⁷ Sanders et al. subsequently reported that this positioning could facilitate fracture reduction and maintenance of alignment.⁸

The suprapatellar approach permits nail insertion with the knee maintained at approximately 20–30° of flexion. This position may facilitate access to the proximal tibial entry point, improve fluoroscopic visualization, and provide better control of the proximal fragment.^{9,10} Nevertheless, the intra-articular nature of the approach raises concerns regarding possible injury to the patellofemoral cartilage, menisci, and other intra-articular structures.^{11,12} Appropriate entry-point positioning and use of a protective sleeve are therefore important.

Several studies have reported satisfactory clinical and radiological outcomes following suprapatellar tibial nailing.^{13,14} Systematic reviews and meta-analyses have also evaluated suprapatellar and infrapatellar approaches, with some reporting potential benefits regarding postoperative pain and selected functional outcomes, although consistent superiority has not been demonstrated for all outcomes.^{15,16}

Aim

To evaluate the functional and radiological outcomes in adults with proximal tibial fractures treated with intramedullary interlocking nails using the suprapatellar technique.

Objectives

1. To evaluate the functional outcomes of AO/OTA 41A2, 41A3, and 41B1 proximal tibial fractures treated using suprapatellar intramedullary nailing.
2. To assess fracture healing and radiological outcomes.
3. To assess postoperative complications, including delayed union, non-union, malunion, infection, knee stiffness, and implant-related complications.

MATERIALS AND METHODS

Study Design and Setting

This was a **single-centre, hospital-based prospective observational study** conducted in the Department of Orthopaedics at **R.N.T. Medical College and Maharana Bhupal Government Hospital, Udaipur, Rajasthan, India**, over one year from April 2024 to March 2025.

R.N.T. Medical College is a medical teaching institution in Udaipur, Rajasthan, providing undergraduate and postgraduate medical education and specialist clinical services. Maharana Bhupal Government Hospital is an associated government teaching hospital providing secondary and tertiary healthcare services, including orthopaedic trauma care and operative management of fractures.

Study Population and Participant Selection

The study population consisted of adults presenting to the Department of Orthopaedics with proximal tibial fractures during the study period.

Participants were selected using a **hospital-based consecutive recruitment approach**, subject to the predefined eligibility criteria. Patients presenting with proximal tibial fractures were assessed clinically and radiologically. Those fulfilling the inclusion criteria and not meeting any exclusion criteria were considered eligible for participation.

The available manuscript reports that 24 patients were ultimately included. However, the numbers of patients screened, excluded, declined, or lost to follow-up were not recorded in the supplied article.

Inclusion Criteria

Patients were included if they:

1. Were aged 18–50 years.
2. Had a closed proximal tibial fracture.
3. Had a fracture classified as AO/OTA 41A2, 41A3, or 41B1.
4. Were medically suitable for operative treatment.

5. Provided informed consent for surgery and participation in follow-up assessment.

Exclusion Criteria

Patients were excluded if they had:

1. An open or compound proximal tibial fracture.
2. A proximal tibial fracture other than AO/OTA 41A2, 41A3, or 41B1.
3. Previous surgery or pre-existing deformity of the involved tibia.
4. A medical contraindication to surgery.
5. A segmental tibial fracture.
6. A pathological proximal tibial fracture.
7. An inability or unwillingness to participate in postoperative follow-up.

Study Size

A total of **24 patients** were included in the study.

The study used a hospital-based recruitment approach, and all eligible patients presenting during the study period who fulfilled the inclusion criteria and consented to participate were included. Consequently, the final sample size was 24 patients.

Preoperative Evaluation

All patients underwent detailed history taking and clinical examination. Assessment included pain, swelling, ecchymosis, deformity, neurovascular status, and associated injuries. Appropriate radiographs were obtained for fracture diagnosis, classification, and operative planning.

Surgical Technique

All patients underwent surgery under spinal anaesthesia. Patients were positioned supine on a radiolucent operating table, with the knee maintained at approximately 20–30° of flexion in the semi-extended position.

A 1.5–2 cm longitudinal incision was made approximately 1 cm proximal to the patella. The quadriceps tendon was exposed and split longitudinally in the midline. The entry point was established slightly lateral to the tibial spine on the anteroposterior view and anterior to the articular margin on the lateral view. A protective sleeve was used during creation of the entry portal.

Following fracture reduction, the guidewire was advanced into the distal fragment under fluoroscopic guidance. Sequential reaming was performed, followed by insertion of an appropriately sized tibial intramedullary nail. Proximal locking was performed using the jig, and distal locking was performed using the freehand technique. Final fracture

reduction and implant position were confirmed fluoroscopically.

A multi-locking tibial nail with a suprapatellar jig and protective sleeve was used in all patients.

Postoperative Management

Patients were monitored postoperatively for neurovascular complications, compartment syndrome, infection, and other adverse events. Early quadriceps and ankle exercises were encouraged. Knee mobilisation and progressive weight-bearing were initiated according to the patient's clinical condition, fracture stability, and radiological progression.

Follow-up

Patients were assessed clinically and radiologically during follow-up. Serial radiographs were obtained to evaluate fracture reduction, alignment, callus formation, and progression toward union.

Functional assessment was performed at 3 and 6 months postoperatively.

Functional Assessment

Functional outcome was assessed using the **Knee Society Score (KSS)**. Outcomes were categorized as excellent, good, fair, or poor according to the study protocol.

Radiological Assessment

Radiological assessment included evaluation of:

- Fracture alignment.
- Maintenance of reduction.
- Callus formation.
- Progression of fracture union.
- Delayed union.
- Non-union.
- Malalignment.
- Implant-related complications.

Future studies should record coronal and sagittal alignment using predefined radiographic methods.

Bias and Measures to Reduce Bias

Potential sources of bias included selection bias, observer bias, information bias, and attrition bias.

The following measures were used or should be documented if they were actually implemented:

1. **Selection bias:** Patients were selected using predefined inclusion and exclusion criteria.
2. **Information bias:** Clinical and radiological assessments were performed using a structured assessment approach.
3. **Observer bias:** Functional and radiological assessments should ideally be performed using

predefined criteria by an assessor who was not directly involved in the surgical procedure.

4. **Attrition bias:** Follow-up visits should be recorded systematically, and reasons for missed visits should be documented.
5. **Confounding:** Important factors such as age, fracture type, injury mechanism, associated injuries, and rehabilitation adherence should be recorded because they may influence functional recovery and fracture union.

Ethical Consideration

Ethical approval was obtained from the R.N.T. Medical College and Maharana Bhupal Government Hospital, Udaipur, Rajasthan, India.

Informed Consent

Written informed consent was obtained from all participants before enrolment. Participants were informed about the

surgical procedure, follow-up assessments, potential risks and benefits, and the use of anonymized clinical information for research purposes. Participation was voluntary, and participants were informed that they could withdraw from the study without affecting their clinical care.

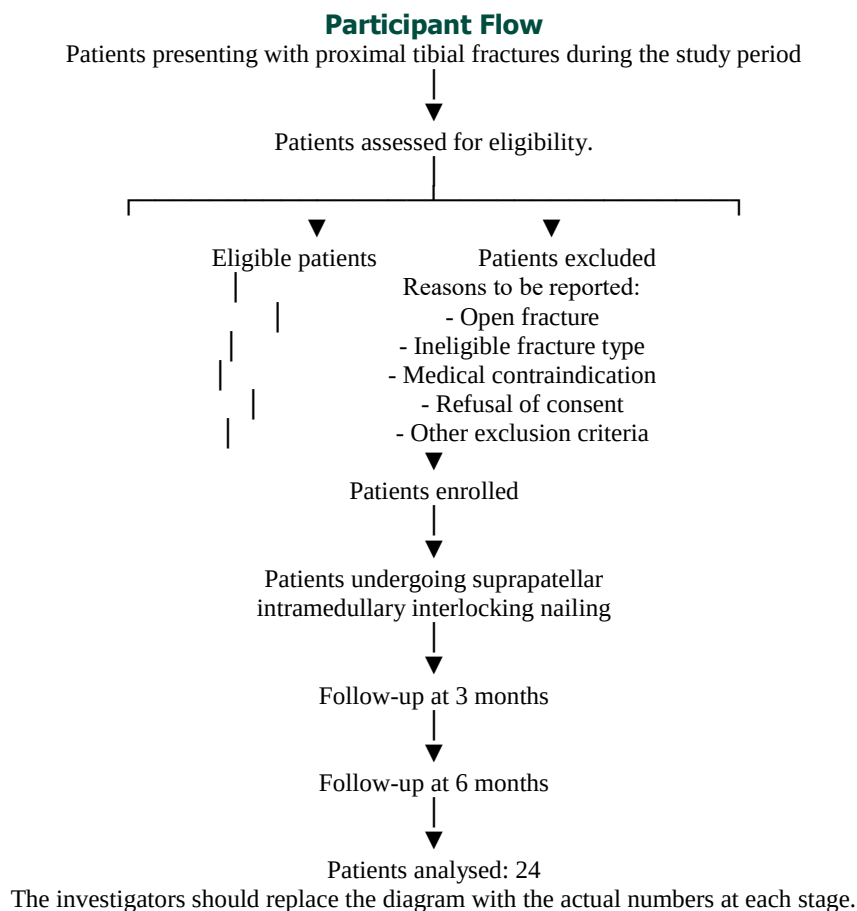
Statistical Analysis

Data were entered into Microsoft Excel and analysed using descriptive statistics. Continuous variables were expressed as means and ranges, while categorical variables were expressed as frequencies and percentages.

RESULTS

Participant Flow

Twenty-four patients were included in the final analysis. Therefore, a complete participant flow diagram was accurately constructed from the data.



Age Distribution

A total of 24 patients were included. The mean age was 33.87 years, with an age range of 19–48 years. The largest proportion of patients belonged to the 31–40-year age group.

Table 1. Age Distribution of Study Participants

Age group (years)	Number	Percentage (%)
18–20	2	8.3
21–30	6	25.0
31–40	9	37.5
41–50	7	29.1
Total	24	100.0

Sex Distribution

Of the 24 patients, 14 (58.3%) were male, and 10 (41.7%) were female. The male-to-female ratio was approximately 1.4:1.

Table 2. Sex Distribution of Study Participants

Sex	Number	Percentage (%)
Male	14	58.3
Female	10	41.7
Total	24	100.0

Fracture Classification

According to the AO/OTA classification, 14 patients (58.3%) had type 41A2 fractures, 6 patients (25.0%) had type 41A3 fractures, and 4 patients (16.7%) had type 41B1 fractures.

Table 3. Distribution According to AO/OTA Fracture Classification

Fracture type	Number	Percentage (%)
41A2	14	58.3
41A3	6	25.0
41B1	4	16.7
Total	24	100.0

Side of Fracture

The fracture involved the right side in 14 patients (58.3%) and the left side in 10 patients (41.7%).

Table 4. Side Distribution of Fractures

Side	Number	Percentage (%)
Right	14	58.3
Left	10	41.7
Total	24	100.0

Mode of Injury

Road traffic accidents were the predominant mechanism of injury, accounting for 20 cases (83.3%). Three patients (12.5%) sustained fractures following a fall from height, and one patient (4.2%) sustained the injury following a self-fall.

Table 5. Mode of Injury

Mode of injury	Number	Percentage (%)
Road traffic accident	20	83.3
Fall from height	3	12.5
Self-fall	1	4.2
Total	24	100.0

Operative Time

The mean operative time was 45.3 minutes, with a reported range of 38–56 minutes.

Table 6. Operative Duration

Operative time (minutes)	Number	Percentage (%)
35–40	4	16.7
41–45	9	37.5
46–50	7	29.2
51–55	3	12.5
56–60	1	4.2
Total	24	100.0

Duration of Hospital Stay

The mean duration of hospital stay was 8.2 days. Eleven patients (45.8%) stayed for 8 days, seven patients (29.2%) stayed for 9 days, four patients (16.7%) stayed for 7 days, and two patients (8.3%) stayed for 10 days.

Table 7. Duration of Hospital Stay

Hospital stay (days)	Number	Percentage (%)
7	4	16.7
8	11	45.8
9	7	29.2
10	2	8.3
Total	24	100.0

Fracture Union

The mean fracture union time was 14.5 weeks. Nine patients (37.5%) achieved union within 10–12 weeks, eight (33.3%) within 13–14 weeks, four (16.7%) within 15–16 weeks, and one (4.2%) within 19–20 weeks. Two patients (8.3%) demonstrated delayed union beyond 20 weeks.

Table 8. Time to Fracture Union

Time to union	Number	Percentage (%)
10–12 weeks	9	37.5
13–14 weeks	8	33.3
15–16 weeks	4	16.7
17–18 weeks	0	0.0
19–20 weeks	1	4.2
>20 weeks	2	8.3
Total	24	100.0

Serial radiographs were obtained during follow-up to assess fracture reduction, alignment, callus formation, and progression of union.

Functional Outcome

Functional outcome was assessed using the Knee Society Score at 3 and 6 months.

At 3 months, 7 patients (29.1%) had excellent outcomes, 9 (37.5%) had good outcomes, 5 (20.8%) had fair outcomes, and 3 (12.5%) had poor outcomes.

At 6 months, 20 patients (83.3%) had excellent outcomes, 2 (8.3%) had good outcomes, 1 (4.2%) had a fair outcome, and 1 (4.2%) had a poor outcome.

The proportion of patients with excellent or good outcomes increased from 16/24 (66.7%) at 3 months to 22/24 (91.7%) at 6 months.

Table 9. Functional Outcome According to the Knee Society Score

Functional outcome	3 months, n (%)	6 months, n (%)
Excellent	7 (29.1)	20 (83.3)
Good	9 (37.5)	2 (8.3)
Fair	5 (20.8)	1 (4.2)
Poor	3 (12.5)	1 (4.2)
Total	24 (100.0)	24 (100.0)

Postoperative Complications

Three patients experienced postoperative complications. Two patients (8.3%) developed knee stiffness, and one patient (4.2%) developed proximal screw loosening. No patient experienced loss of fracture reduction or progressive displacement during follow-up.

Table 10. Postoperative Complications

Complication	Number	Percentage (%)
Knee stiffness	2	8.3
Proximal screw loosening	1	4.2
Loss of reduction	0	0.0
Progressive displacement	0	0.0

DISCUSSION

The present prospective observational study evaluated the functional and radiological outcomes of 24 adults with selected proximal tibial fractures treated using intramedullary interlocking nailing through a suprapatellar approach. Progressive improvement in functional outcomes was observed during follow-up, with satisfactory fracture healing and a low frequency of reported postoperative complications.

The mean age of the study population was 33.87 years, and males constituted 58.3% of the sample. Road traffic accidents were the predominant mechanism of injury, accounting for 83.3% of cases. This predominance of high-

energy mechanisms is consistent with previously reported epidemiological patterns of tibial fractures.¹⁷

AO/OTA 41A2 was the most common fracture pattern, accounting for 58.3% of cases. Proximal tibial fractures may be technically challenging because of the wide metaphyseal canal and the deforming forces acting on the proximal fragment, which may predispose patients to malalignment.^{18,19}

The mean operative time was 45.3 minutes, and the average hospital stay was 8.2 days. The suprapatellar technique allows nail insertion with the knee maintained in a semi-extended position and may facilitate access to the proximal tibial entry point and control of the proximal fragment.^{7,8,10}

The mean fracture union time was 14.5 weeks. Most patients achieved union within 10–16 weeks, whereas two patients demonstrated delayed union beyond 20 weeks. Kulkarni et al. evaluated 43 proximal-third tibial fractures treated with suprapatellar nailing and reported satisfactory clinical and radiological outcomes, although delayed union and non-union occurred in some patients.¹⁴ Direct comparison should be made cautiously because of differences in sample size, fracture patterns, follow-up duration, and study design.

No loss of reduction or progressive displacement was reported in the present series. This finding may reflect careful intraoperative reduction, appropriate implant positioning, and the potential mechanical advantages of semi-extended positioning. However, standardized angular measurements were not reported, limiting the objective assessment of alignment.

Functional outcomes improved between 3 and 6 months. At 3 months, 16 patients (66.7%) had excellent or good outcomes, compared with 22 patients (91.7%) at 6 months. This improvement may be associated with fracture consolidation, restoration of knee movement, rehabilitation, and gradual progression of weight-bearing activities.

Previous studies have reported satisfactory clinical and radiological outcomes following suprapatellar tibial nailing.^{13,14} Systematic reviews comparing suprapatellar and infrapatellar nailing have reported possible benefits regarding postoperative pain and selected functional outcomes, although superiority has not been demonstrated consistently for union, infection, operative time, or all complication outcomes.^{15,16}

Two patients developed postoperative knee stiffness. Stiffness was managed conservatively with rehabilitation. Anterior knee symptoms remain an important consideration following tibial intramedullary nailing. The suprapatellar approach may facilitate positioning and fracture reduction, but its intra-articular nature requires careful attention to portal placement and protective instrumentation.

The use of a protective sleeve in all patients was an important technical precaution. Cadaveric and clinical studies have emphasized the possibility of injury to the patellofemoral cartilage and other intra-articular structures during suprapatellar nailing.^{11,12,23}

Generalizability

The findings may be applicable to adults aged 18–50 years with selected closed proximal tibial fractures classified as AO/OTA 41A2, 41A3, or 41B1 who are treated in a hospital with appropriate orthopaedic trauma and fluoroscopic facilities.

However, generalizability is limited because the study was conducted at a single institution, included only 24

participants, excluded open and complex fracture patterns, and had no comparison group. The findings may not be directly applicable to older adults, patients with osteoporosis, open fractures, pathological fractures, polytrauma, segmental fractures, or more complex proximal tibial injuries.

CONCLUSION

Suprapatellar intramedullary interlocking nailing in the semi-extended position produced satisfactory functional and radiological outcomes in this series of 24 adults with selected proximal tibial fractures.

The mean fracture union time was 14.5 weeks, and most fractures united within 10–16 weeks. Functional outcomes improved between 3 and 6 months, with 83.3% of patients demonstrating excellent outcomes at 6 months.

The suprapatellar technique may facilitate access to the proximal tibial entry point and maintenance of fracture reduction and alignment. Nevertheless, postoperative knee stiffness and implant-related complications may occur.

Limitations

1. The study included only 24 patients.
2. It was conducted at a single centre.
3. There was no control or comparison group.
4. The follow-up period was limited to 6 months.
5. The study used descriptive statistics only.
6. Standardized angular measurements of radiological alignment were not reported.
7. The precise Knee Society Score thresholds used for outcome categorization were not provided.
8. The participant screening and exclusion numbers were not documented.
9. Potential confounding factors, including rehabilitation adherence and associated injuries, were not analysed.
10. The findings may not be generalizable to older patients, open fractures, complex fracture patterns, or patients with substantial comorbidities.

Recommendation

Larger multicentre prospective comparative studies should be conducted to compare suprapatellar and infrapatellar approaches using standardized functional scores, objective radiological alignment measurements, validated pain assessments, and longer follow-up. Future studies should also include formal sample-size calculations, detailed participant-flow reporting, assessor blinding where feasible, and systematic documentation of complications and reoperations.

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LIST OF ABBREVIATIONS

- **AO/OTA:** Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association
- **KSS:** Knee Society Score
- **R.N.T.:** Ravindra Nath Tagore
- **HOD:** Head of Department
- **AP:** Anteroposterior
- **ROM:** Range of motion

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest related to this study.

AUTHOR CONTRIBUTIONS

The following contribution statement should be verified by all authors before submission:

Dr. Chandraveer Singh Rao: Study conception, study coordination, surgical management, data collection, and manuscript preparation.

Dr. Vikas Meena: Literature review, clinical data collection, and manuscript revision.

Dr. Naresh Saini: Study supervision, clinical oversight, and critical revision of the manuscript.

Dr. M.P. Jain: Clinical assistance, data interpretation, and manuscript review.

Dr. Anurag Talesara: Clinical assessment, data collection, and manuscript revision.

Dr. Anamendra Sharma: Senior supervision, methodological review, and final approval of the manuscript.

Dr. Jyoti: Perioperative anaesthetic management, clinical coordination, and manuscript review.

All authors: Reviewed and approved the final manuscript and agreed to be accountable for the accuracy and integrity of the work.

DATA AVAILABILITY

The manuscript analysed during the present study is not publicly available because they contain clinical information from individual patients but may be available from the corresponding author on reasonable request, subject to institutional approval and applicable confidentiality requirements.

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