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Prospective Observational Study of Functional and Radiological Outcomes of Extraarticular Proximal Tibia Fractures Treated with Suprapatellar Tibia Intramedulary Nailing

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ABSTRACT

Background: Extra-articular proximal tibial fractures present significant management challenges due to metaphyseal anatomy, deforming forces, and limited soft tissue coverage. Suprapatellar intramedullary nailing (SPN-IMN) has emerged as a minimally invasive technique aimed at improving alignment and functional outcomes.

Methods: This prospective observational study was conducted on 25 patients with extra-articular proximal tibial fractures treated with SPN-IMN at a tertiary care center over 18 months. Patients aged 20–50 years with closed or Gustilo-Anderson Grade I open fractures were included. Functional outcomes were assessed using the Knee Society Score (KSS), and radiological outcomes were evaluated based on alignment and callus formation. Patients were followed up at 1, 3, 6, and 9 months.

Results: The majority of patients were young males, with road traffic accidents being the most common mechanism of injury (88%). Functional outcomes improved progressively, with mean KSS increasing from 63.00 at 1 month to 85.12 at 9 months. At final follow-up, 72% of patients achieved excellent results. Radiological assessment showed satisfactory alignment in 80% of cases. Complications were minimal, with superficial infection in 8%, deep infection in 4%, malunion in 16%, and nonunion in 8%. Early weight bearing (mean 2.92 weeks) and good knee range of motion (mean 125.64°) were observed.

Conclusion: SPN-IMN is an effective and minimally invasive technique for extra-articular proximal tibial fractures, providing good functional recovery, satisfactory alignment, and low complication rates.

Keywords: Proximal tibia fracture, suprapatellar intramedullary nailing, extra-articular fractures, Knee Society Score, functional outcome.

INTRODUCTION

Proximal extra-articular tibial fractures account for approximately 5–11% of all tibial shaft fractures and represent a distinct subset with unique anatomical and biomechanical challenges [1]. The proximal tibial metaphysis is characterized by a wide medullary canal and relatively thin soft tissue envelope, which complicates fracture management and increases the risk of instability and soft tissue complications. These fractures are frequently the result of high-energy trauma and are often associated with significant soft tissue injury [2]. Furthermore, deforming forces generated by the patellar ligament anteriorly and the triceps surae posteriorly contribute to difficulties in maintaining alignment, particularly in the sagittal and coronal planes. Given that the knee joint plays a crucial role in weight-bearing and mobility, restoration of alignment, preservation of soft tissue integrity, and achievement of stable fixation are essential for early rehabilitation and optimal functional outcomes [3].

Various treatment modalities have been employed for the management of these fractures, including conservative methods, external fixation, intramedullary nailing (IMN), and plate osteosynthesis. Non-operative treatment is associated with higher rates of complications such as malunion, nonunion, rotational deformities, and knee stiffness [4–6]. External fixation is often reserved for cases with severe soft tissue injury but is limited by patient discomfort, pin tract infections, and suboptimal stability [7–10].

Intramedullary nailing has gained widespread acceptance due to its minimally invasive nature and preservation of periosteal blood supply. However, conventional infrapatellar nailing techniques may be associated with malalignment and inadequate fixation in proximal tibial fractures due to the metaphyseal flare and mismatch between the nail and canal diameter [2,4–10]. Plate fixation, while allowing anatomical reduction, often necessitates extensive soft tissue dissection, increasing the risk of wound complications and vascular compromise [2,7,11–14].

Recent advancements such as suprapatellar intramedullary nailing, use of blocking screws, and minimally invasive plate osteosynthesis (MIPO) have been introduced to address these limitations and improve alignment and stability [16–18]. Among these, the suprapatellar approach has shown promise in achieving better fracture alignment and facilitating ease of reduction, particularly in proximal fractures.

Despite these developments, there remains a paucity of focused prospective studies evaluating the functional and radiological outcomes of extra-articular proximal tibial fractures treated specifically with suprapatellar intramedullary nailing. Therefore, the present study aims to assess the effectiveness of this technique in terms of fracture union, alignment, and functional recovery, thereby contributing to evidence-based clinical decision-making

MATERIAL AND METHODS

This prospective observational study was conducted in the Department of Orthopaedics and Trauma Centre at GRMC, Gwalior (M.P.), over a period of 18 months after obtaining approval from the Institutional Ethics Committee. All patients provided written informed consent in their vernacular language prior to inclusion. A total of 25 adult patients with extra-articular proximal tibial fractures treated with suprapatellar intramedullary nailing were enrolled in the study. Patients were evaluated preoperatively through detailed history, clinical examination, and relevant laboratory investigations as per institutional protocol.

Sample size was determined based on feasibility and expected case load during the study period. A total of 25 patients were included to ensure adequate assessment of functional and radiological outcomes.

Inclusion Criteria

- Age 20–50 years
- Patients with extra-articular proximal tibial fractures
- Closed fractures and Gustilo-Anderson Grade I open fractures
- Patients willing to participate and provide informed consent

Exclusion Criteria

- Patients not providing consent
- Intra-articular extension of fracture
- Polytrauma or multiple long bone fractures
- Pathological fractures
- Pre-existing arthritic knee conditions
- Patients lost to follow-up

METHODOLOGY

Preoperative evaluation and preparation: All patients underwent detailed preoperative assessment including demographic data (age, sex), mechanism of injury, and associated comorbidities. Laboratory investigations included complete blood count, renal function tests, liver function tests, random blood sugar, coagulation profile, and viral markers. Radiological evaluation included anteroposterior and lateral radiographs of the affected limb, with computed tomography performed when required for better fracture delineation. Pre-anesthetic evaluation was carried out in all cases.

Procedure and intraoperative assessment: All patients underwent fixation using suprapatellar intramedullary tibial nailing under spinal anesthesia. Patients were positioned supine on a radiolucent table with slight knee flexion. Closed reduction was achieved under fluoroscopic guidance. A suprapatellar approach was used for entry, followed by guide wire insertion, sequential reaming, and placement of an appropriately sized intramedullary nail. Proximal and distal interlocking screws were inserted based on fracture configuration to ensure stability. Intraoperative parameters such as duration of surgery, need for additional reduction techniques, and intraoperative complications were recorded.

Postoperative monitoring: Postoperatively, patients were administered intravenous antibiotics, analgesics, and supportive care. Early mobilization and physiotherapy were initiated as tolerated. Wound inspection was performed regularly during hospital stay. Patients were followed up at 1, 3, 6, and 9 months with clinical and radiological evaluation.

Functional outcome assessment: Functional outcome was assessed using the Knee Society Score (KSS), which evaluates walking distance and stair-climbing ability. Scores were recorded at each follow-up visit to assess recovery and functional improvement.

Radiological assessment: Radiological outcomes were evaluated using serial radiographs at each follow-up. Parameters assessed included fracture alignment (coronal and sagittal planes), callus formation, and time to union. Malalignment and delayed union were also noted where applicable.

Outcomes

The primary outcome measured was functional outcome based on the Knee Society Score. Secondary outcomes included radiological union, time to fracture healing, maintenance of alignment, and incidence of complications such as infection, malunion, or delayed union.

Statistical Analysis

All data were entered into Microsoft Excel and analyzed using SPSS software version 25.0. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. A p-value <0.05 was considered statistically significant.

RESULTS

The present study included 25 patients with extra-articular proximal tibial fractures treated with suprapatellar intramedullary nailing. All patients were followed up for a period of 9 months, and functional as well as radiological outcomes were assessed. The majority of patients belonged to the younger age group. Patients aged 18–30 years constituted 36%, followed by 31–40 years (32%) and 41–50 years (32%). The study showed a clear male predominance, with 20 patients (80%) being male and 5 patients (20%) female. Right-sided fractures were more common (56%) compared to left-sided fractures (44%). Road traffic accidents were the most common mechanism of injury, accounting for 88% of cases, followed by assault (8%) and fall from height (4%). According to AO/OTA classification, type A3 fractures were most common (44%), followed by A1 (28%) and A2 (28%). Associated fibular fractures were present in 88% of patients.

Table 1: Demographic and Injury Profile (N = 25)

Parameter	Category	Frequency (n)	Percentage (%)
Age Group	18–30 years	9	36
	31–40 years	8	32
	41–50 years	8	32
Gender	Male	20	80
	Female	5	20
Side	Right	14	56
	Left	11	44
Mechanism of Injury	RTA	22	88
	Assault	2	8
	Fall from height	1	4
AO/OTA Type	A1	7	28
	A2	7	28
	A3	11	44
Fibula Fracture	Present	22	88
	Absent	3	12

Intraoperative parameters showed that the mean time from injury to surgery was 4.88 ± 1.71 days, and the mean surgical duration was 68.28 ± 12.66 minutes. The mean fluoroscopy time was 91.00 ± 19.28 seconds, while the mean intraoperative blood loss was 102.92 ± 22.13 ml. The average incision size was 3.84 cm.

Table 2: Intraoperative Parameters

Parameter	Mean ± SD	Minimum	Maximum
Time from injury to surgery (days)	4.88 ± 1.71	1	8
Surgical time (minutes)	68.28 ± 12.66	39	90
Fluoroscopy time (seconds)	91.00 ± 19.28	52	131
Blood loss (ml)	102.92 ± 22.13	64	144
Incision size (cm)	3.84 ± 0.87	1.5	4.5

Functional outcomes assessed using the Knee Society Score (KSS) showed progressive improvement over time. The mean KSS increased from 63.00 ± 7.91 at 1 month to 85.12 ± 11.89 at 9 months, indicating significant functional recovery.

Table 3: Functional Outcome (KSS Over Time)

Follow-up	Mean KSS ± SD	Minimum	Maximum
1 Month	63.00 ± 7.91	50	76
3 Months	71.40 ± 10.53	51	87
6 Months	78.84 ± 11.17	55	93
9 Months	85.12 ± 11.89	48	99

At final follow-up, excellent outcomes were observed in 72% of patients, good in 16%, fair in 4%, and poor in 8%.

Table 4: Final Functional Outcome (KSS Category)

Outcome	Frequency (n)	Percentage (%)
Excellent	18	72
Good	4	16
Fair	1	4
Poor	2	8

Radiological evaluation showed satisfactory alignment in 80% of patients. Malalignment was minimal, with varus deformity in 8%, valgus in 4%, AP malalignment in 4%, and fracture step in 4%.

Table 5: Radiological Outcome

Parameter	Frequency (n)	Percentage (%)
Satisfactory alignment	20	80
Varus malalignment	2	8
Valgus malalignment	1	4
AP malalignment	1	4
Fracture step	1	4

Complications were relatively low. Malunion was observed in 16% of patients, while nonunion occurred in 8%. Superficial infection was seen in 8% and deep infection in 4% of cases. The majority (88%) had no complications.

Table 6: Complications

Complication	Frequency (n)	Percentage (%)
No complication	22	88
Superficial infection	2	8
Deep infection	1	4
Malunion	4	16
Nonunion	2	8

Postoperative recovery parameters showed early mobilization. The mean time to weight bearing was 2.92 ± 0.88 weeks, and the mean knee range of motion at 9 months was 125.64° ± 22.79°.

Table 7: Postoperative Recovery Parameters

Parameter	Mean ± SD	Minimum	Maximum
Weight bearing time (weeks)	2.92 ± 0.88	2	5
Knee ROM at 9 months (degrees)	125.64 ± 22.79	111	149

Overall, the study demonstrated favorable functional and radiological outcomes with suprapatellar intramedullary nailing, with high rates of satisfactory alignment, early mobilization, and low complication rates.

DISCUSSION

Extra-articular proximal tibial fractures remain a therapeutic challenge due to the metaphyseal anatomy, deforming muscular forces, and limited soft tissue envelope around the knee. The present prospective observational study evaluated the functional and radiological outcomes of these fractures managed exclusively with suprapatellar intramedullary nailing (SPN-IMN). The findings demonstrate that this technique provides reliable fixation with favorable functional recovery, acceptable alignment, and low complication rates.

In our study, the majority of patients were young males, with 80% being male and most belonging to the 18–40-year age group. Road traffic accidents accounted for 88% of injuries, reflecting the high-energy mechanism typically associated with proximal tibial fractures. These observations are consistent with previous literature, which reports a predominance of such injuries among active, working-age males exposed to high-velocity trauma [19,20]. The predominance of AO/OTA type A3 fractures (44%) in our cohort further indicates the complex nature of injuries encountered, comparable with earlier studies [21-23].

The intraoperative parameters in our study highlight the minimally invasive nature of the suprapatellar approach. The mean surgical duration (68.28 minutes), low intraoperative blood loss (approximately 103 ml), and small incision size (3.84 cm) are consistent with previous reports emphasizing reduced soft tissue disruption with intramedullary nailing [24–26]. Although fluoroscopy time was moderately higher (mean 91 seconds), this is expected in closed reduction techniques and is considered an acceptable trade-off for improved biological preservation.

Functional outcomes showed a steady and significant improvement over time. The mean Knee Society Score (KSS) improved from 63.00 at one month to 85.12 at nine months, with 72% of patients achieving excellent outcomes. These findings are comparable to those reported by Jones et al. and Bi et al., who demonstrated superior functional outcomes with the suprapatellar approach, attributed to improved alignment, reduced anterior knee pain, and facilitation of early mobilization [27,28]. The mean knee range of motion at final follow-up (125.64°) further supports satisfactory functional recovery.

Radiologically, 80% of patients achieved satisfactory alignment, with minimal malalignment observed. Varus deformity was the most common (8%), followed by valgus and anterior-posterior malalignment (4% each). These findings are in line with previous studies that report challenges in maintaining alignment in proximal tibial fractures due to metaphyseal widening and deforming forces [29]. Careful attention to entry point and intraoperative reduction techniques likely contributed to the acceptable alignment outcomes in this study. The literature also supports the use of adjuncts such as blocking screws to improve alignment, particularly in proximal fractures [30–32].

The complication profile in our study was favorable. Superficial infection occurred in 8% of patients and deep infection in 4%, which aligns with previously reported low infection rates associated with intramedullary fixation due to minimal soft tissue handling [56]. Malunion was observed in 16% and nonunion in 8% of cases. Malalignment-related complications are well-documented in proximal tibial nailing and are often attributed to difficulty in controlling the proximal fragment during reduction [33,34].

Early rehabilitation is a key advantage of SPN-IMN. The mean time to weight bearing in our study was 2.92 weeks, indicating rapid functional recovery. Early mobilization has been shown to reduce complications such as joint stiffness and muscle wasting while improving overall outcomes [35]. The progressive improvement in KSS across follow-up intervals further reinforces the role of early rehabilitation in achieving favorable outcomes.

The strengths of this study include its prospective design and focused evaluation of a single surgical modality, which eliminates intergroup variability and allows a clearer assessment of outcomes associated with suprapatellar nailing. However, certain limitations must be acknowledged. The relatively small sample size and lack of a comparison group limit the generalizability of the findings. Additionally, the follow-up duration of nine months may not be sufficient to assess long-term complications such as implant-related issues or late functional deficits.

CONCLUSION

This prospective observational study demonstrates that suprapatellar intramedullary nailing (SPN-IMN) is an effective and reliable modality for managing extra-articular proximal tibial fractures. The technique provided favorable functional outcomes, with the majority of patients achieving excellent Knee Society Scores and good range of motion at final follow-up. Radiological outcomes were satisfactory in most cases, with acceptable alignment and union rates. Early weight bearing and low complication rates further support its clinical utility. However, attention to reduction technique is essential to avoid malalignment. Overall, SPN-IMN offers a minimally invasive approach with good functional recovery and should be considered a preferred treatment option.

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