Original Research Article

A Comparative Cross-Sectional Study of Functional and Radiological Outcomes in Patients with Proximal Tibia Fractures Managed by Suprapatellar versus Infrapatellar Intramedullary Nailing

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Abstract

Background: Proximal tibia fractures are challenging injuries due to their anatomical location and tendency for malalignment. Intramedullary nailing is the preferred treatment modality; however, the optimal approach suprapatellar versus infrapatellar remains a topic of debate. Aim: To compare the functional and radiological outcomes in patients with proximal tibia fractures managed by suprapatellar versus infrapatellar intramedullary nailing. **Methods:** This hospital-based comparative cross-sectional study included 200 patients with proximal tibia fractures, divided into two groups: suprapatellar (n = 100) and infrapatellar (n = 100) intramedullary nailing. Functional outcomes were assessed using Lysholm knee score, range of motion, pain (VAS), and time to full weight-bearing. Radiological outcomes included time to union, alignment, and incidence of malunion. Complications such as anterior knee pain, infection, and non-union were also evaluated. Statistical analysis was performed using t-test and chi-square test, with $p < 0.05$ considered significant. **Results:** The suprapatellar group demonstrated significantly better functional outcomes, including higher Lysholm scores (86.74 ± 8.92 vs 80.93 ± 10.41, $p < 0.001$), improved knee flexion ($p < 0.001$), lower pain scores ($p < 0.001$), and earlier full weight-bearing ($p < 0.001$). Radiologically, the suprapatellar group showed earlier union ($p = 0.003$) and significantly lower malalignment and malunion rates ($p < 0.05$). The incidence of anterior knee pain and overall complications was significantly lower in the suprapatellar group ($p < 0.05$). **Conclusion:** Suprapatellar intramedullary nailing provides superior functional and radiological outcomes with fewer complications compared to infrapatellar nailing, making it a preferable surgical technique for proximal tibia fractures.

Keywords: Proximal tibia fracture. Suprapatellar intramedullary nailing. Infrapatellar intramedullary nailing.

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INTRODUCTION

Proximal tibia fractures constitute a significant proportion of long bone injuries, often resulting from high-energy trauma such as road traffic accidents, falls from height, or sports-related injuries. These fractures are clinically important due to their proximity to the knee joint, which plays a crucial role in weight-bearing, mobility, and functional independence. Management of proximal tibial fractures remains challenging because of factors such as the metaphyseal flare, tendency for malalignment, soft tissue compromise, and risk of postoperative

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complications including infection, non-union, and knee stiffness.[1]

Intramedullary nailing has emerged as one of the preferred treatment modalities for proximal tibial fractures due to its minimally invasive nature, preservation of soft tissue integrity, and early mobilization benefits. However, conventional infrapatellar intramedullary nailing has been associated with several technical challenges, particularly in proximal third tibial fractures. These include difficulty in achieving proper alignment, increased risk of anterior angulation (apex anterior deformity), and the need for excessive manipulation due to the pull of the quadriceps muscle. Additionally, infrapatellar nailing often requires knee flexion during the procedure, which may compromise fracture reduction and lead to suboptimal outcomes.[2]

In recent years, the suprapatellar approach for intramedullary nailing has gained increasing popularity as an alternative technique. This approach involves insertion of the nail through the patellofemoral joint with the knee in a semi-extended position, thereby facilitating better alignment and ease of reduction. The semi-extended position reduces deforming forces, allows improved fluoroscopic visualization, and enhances surgeon control during the procedure. Several studies have reported improved radiological alignment and reduced malunion rates with the suprapatellar technique compared to the traditional infrapatellar approach.[3][4]

AIM

To compare the functional and radiological outcomes in patients with proximal tibia fractures managed by suprapatellar versus infrapatellar intramedullary nailing.

OBJECTIVES

1. To assess and compare the functional outcomes between suprapatellar and infrapatellar intramedullary nailing in proximal tibia fractures.
2. To evaluate and compare radiological outcomes such as alignment, union time, and malunion between the two techniques.
3. To compare the incidence of complications including anterior knee pain, infection, and non-union between both surgical approaches.

MATERIAL AND METHODOLOGY

Source of Data

The data were collected from patients diagnosed with proximal tibia fractures admitted to the Department of Orthopedics at a tertiary care teaching hospital.

Study Design

This was a hospital-based comparative cross-sectional study.

Study Location

The study was conducted at the Department of Orthopedics in a tertiary care hospital.

Study Duration

The study was carried out over a period of two years, including patient recruitment, surgical intervention, and follow-up.

Sample Size

A total of 200 patients with proximal tibia fractures were included in the study and divided into two groups:

- Group A: Suprapatellar intramedullary nailing (n = 100)
- Group B: Infrapatellar intramedullary nailing (n = 100)

Inclusion Criteria

- Patients aged ≥18 years
- Patients with proximal third tibial fractures
- Both closed and Gustilo-Anderson type I and II open fractures
- Patients willing to participate and provide informed consent

Exclusion Criteria

- Patients below 18 years of age
- Pathological fractures
- Gustilo-Anderson type III open fractures
- Patients with associated neurovascular injury
- Patients with previous surgery on the affected limb
- Patients unwilling for follow-up

Procedure and Methodology

After obtaining institutional ethical committee approval and informed consent, eligible patients were enrolled in the study. Patients were divided into two groups based on the surgical technique used.

In the suprapatellar group, intramedullary nailing was performed in a semi-extended knee position using a suprapatellar entry point through the patellofemoral joint with protective instrumentation. In the infrapatellar group, the procedure was carried out with the knee in flexion using the conventional infrapatellar entry approach.

Standard surgical protocols, aseptic precautions, and perioperative antibiotic prophylaxis were followed in all cases. Postoperative rehabilitation protocols including early mobilization and physiotherapy were standardized for both groups.

Patients were followed up at regular intervals (6 weeks, 3 months, 6 months, and 1 year). Functional outcomes were assessed using validated scoring systems such as Lysholm knee score or Knee Society Score. Radiological outcomes were evaluated using X-rays to assess alignment, union, and complications.

Sample Processing

Clinical and radiological data were recorded in a structured proforma. Functional scores were calculated during follow-up visits. Radiographs were analyzed for alignment (varus/valgus and anterior/posterior angulation), time to union, and presence of complications such as delayed union or non-union.

Statistical Methods

Data were entered into Microsoft Excel and analyzed using SPSS software version 25.0. Quantitative data were expressed as mean ± standard deviation, while qualitative data were presented as frequency and percentage.

- Independent t-test was used for comparison of means
- Chi-square test/Fisher's exact test was used for categorical variables
- A p-value <0.05 was considered statistically significant

Data Collection

Data were collected using a predesigned and pretested case record form. Information regarding demographic details, mechanism of injury, fracture type, surgical procedure, intraoperative findings, and postoperative outcomes were recorded. Follow-up data included functional scores, radiological findings, and complications.

OBSERVATION AND RESULTS

TABLE 1. Baseline characteristics of patients with proximal tibia fractures managed by suprapatellar versus infrapatellar intramedullary nailing (N = 200)

Variable	Suprapatellar (n=100)	Infrapatellar (n=100)	Test of significance	95% CI	p value
Age (years), Mean ± SD	41.82 ± 12.46	42.97 ± 11.88	Unpaired t = 0.67	Mean difference: -4.53 to 2.23	0.504
Male sex, n (%)	68 (68.0%)	71 (71.0%)	$\chi^2 = 0.22$	OR: 0.87 (0.47-1.62)	0.640
Female sex, n (%)	32 (32.0%)	29 (29.0%)	$\chi^2 = 0.22$	OR: 1.15 (0.62-2.13)	0.640
Right-sided fracture, n (%)	57 (57.0%)	54 (54.0%)	$\chi^2 = 0.18$	OR: 1.13 (0.64-1.99)	0.673
Left-sided fracture, n (%)	43 (43.0%)	46 (46.0%)	$\chi^2 = 0.18$	OR: 0.88 (0.50-1.56)	0.673
Mode of injury - Road traffic accident, n (%)	61 (61.0%)	64 (64.0%)	$\chi^2 = 0.19$	OR: 0.88 (0.50-1.54)	0.664
Mode of injury - Fall, n (%)	27 (27.0%)	24 (24.0%)	$\chi^2 = 0.24$	OR: 1.17 (0.62-2.22)	0.626
Mode of injury - Sports/other trauma, n (%)	12 (12.0%)	12 (12.0%)	$\chi^2 = 0.00$	OR: 1.00 (0.42-2.37)	1.000
Closed fracture, n (%)	81 (81.0%)	78 (78.0%)	$\chi^2 = 0.27$	OR: 1.20 (0.60-2.40)	0.603
Open fracture (Type I/II), n (%)	19 (19.0%)	22 (22.0%)	$\chi^2 = 0.27$	OR: 0.83 (0.42-1.67)	0.603
Time from injury to surgery (days), Mean ± SD	3.74 ± 1.61	3.91 ± 1.72	Unpaired t = 0.72	Mean difference: -0.64 to 0.30	0.470
Operative duration (minutes), Mean ± SD	88.43 ± 14.27	94.16 ± 15.32	Unpaired t = 2.73	Mean difference: -9.87 to -1.59	0.007*

Table 1 shows the baseline demographic and clinical characteristics of patients with proximal tibia fractures managed by suprapatellar and infrapatellar intramedullary nailing. The mean age in the suprapatellar group was 41.82 ± 12.46 years, while in the infrapatellar group it was 42.97 ± 11.88 years, with no statistically significant difference ($t = 0.67$, $p = 0.504$). The gender distribution was comparable between the groups, with males constituting 68.0% in the suprapatellar group and 71.0% in the infrapatellar group ($\chi^2 = 0.22$, $p = 0.640$). Similarly, the laterality of fracture did not differ significantly, with right-sided fractures seen in 57.0% and 54.0% of patients respectively ($p = 0.673$).

Regarding the mechanism of injury, road traffic accidents were the most common cause in both groups (61.0% vs 64.0%), followed by falls (27.0% vs 24.0%) and sports or other trauma (12.0% in both groups), with no statistically significant differences. The proportion of closed fractures was also similar (81.0% vs 78.0%, $p = 0.603$). The mean time from injury to surgery was comparable between the two groups (3.74 ± 1.61 vs 3.91 ± 1.72 days, $p = 0.470$). However, the operative duration was significantly shorter in the suprapatellar group (88.43 ± 14.27 minutes) compared to the infrapatellar group (94.16 ± 15.32 minutes), which was statistically significant ($t = 2.73$, $p = 0.007$.

TABLE 2. Comparison of functional outcomes between suprapatellar and infrapatellar intramedullary nailing in proximal tibia fractures (N = 200)

Variable	Suprapatellar (n=100)	Infrapatellar (n=100)	Test of significance	95% CI	p value
Lysholm knee score at 6 months, Mean ± SD	86.74 ± 8.92	80.93 ± 10.41	Unpaired t = 4.24	Mean difference: 3.11 to 8.51	<0.001*
Knee flexion at final follow-up (degrees), Mean ± SD	124.83 ± 11.24	118.29 ± 13.17	Unpaired t = 3.78	Mean difference: 3.12 to 9.96	<0.001*
Extension lag present, n (%)	9 (9.0%)	18 (18.0%)	$\chi^2 = 3.58$	OR: 0.45 (0.19-1.05)	0.058
Anterior knee pain during walking, n (%)	14 (14.0%)	29 (29.0%)	$\chi^2 = 6.66$	OR: 0.40 (0.20-0.80)	0.010*
Pain VAS score at 6 months, Mean ± SD	2.18 ± 1.14	3.36 ± 1.42	Unpaired t = 6.49	Mean difference: -1.54 to -0.82	<0.001*
Return to unaided full weight bearing (weeks), Mean ± SD	10.42 ± 2.11	11.63 ± 2.49	Unpaired t = 3.72	Mean difference: -1.85 to -0.57	<0.001*
Excellent/Good functional outcome, n (%)	84 (84.0%)	71 (71.0%)	$\chi^2 = 4.95$	OR: 2.14 (1.09-4.18)	0.026*
Fair/Poor functional outcome, n (%)	16 (16.0%)	29 (29.0%)	$\chi^2 = 4.95$	OR: 0.47 (0.24-0.92)	0.026*

Table 2 compares the functional outcomes between suprapatellar and infrapatellar intramedullary nailing in proximal tibia fractures. The mean Lysholm knee score at 6 months was significantly higher in the suprapatellar group (86.74 ± 8.92) compared to the infrapatellar group (80.93 ± 10.41), indicating better functional recovery ($t = 4.24$, $p < 0.001$). Similarly, knee flexion at final follow-up was significantly greater in the suprapatellar group (124.83 ± 11.24°) than in the infrapatellar group (118.29 ± 13.17°, $p < 0.001$).

Extension lag was observed less frequently in the suprapatellar group (9.0%) compared to the infrapatellar group (18.0%), although this difference did not reach statistical significance ($p = 0.058$). Anterior knee pain during walking was significantly lower in the suprapatellar group (14.0%) compared to the infrapatellar group (29.0%) ($\chi^2 = 6.66$, $p = 0.010$). The mean pain VAS score was also significantly lower in the suprapatellar group (2.18 ± 1.14 vs 3.36 ± 1.42, $p < 0.001$). Additionally, patients in the suprapatellar group achieved full weight bearing earlier (10.42 ± 2.11 weeks) compared to the infrapatellar group (11.63 ± 2.49 weeks), which was statistically significant ($p < 0.001$). A higher proportion of patients in the suprapatellar group had excellent or good functional outcomes (84.0% vs 71.0%), while fair or poor outcomes were more common in the infrapatellar group (29.0% vs 16.0%), both showing statistical significance ($p = 0.026$).

TABLE 3. Comparison of radiological outcomes such as alignment, union time, and malunion between suprapatellar and infrapatellar intramedullary nailing (N = 200)

Variable	Suprapatellar (n=100)	Infrapatellar (n=100)	Test of significance	95% CI	p value
Time to radiological union (weeks), Mean ± SD	18.64 ± 3.12	20.11 ± 3.86	Unpaired t = 2.98	Mean difference: -2.44 to -0.50	0.003*
Coronal malalignment >5°, n (%)	8 (8.0%)	19 (19.0%)	$\chi^2 = 5.32$	OR: 0.37 (0.15-0.88)	0.021*
Sagittal malalignment >5°, n (%)	7 (7.0%)	17 (17.0%)	$\chi^2 = 4.69$	OR: 0.37 (0.14-0.95)	0.030*
Any malunion, n (%)	11 (11.0%)	24 (24.0%)	$\chi^2 = 5.89$	OR: 0.39 (0.18-0.85)	0.015*
Acceptable alignment achieved, n (%)	89 (89.0%)	76 (76.0%)	$\chi^2 = 5.89$	OR: 2.56 (1.18-5.54)	0.015*
Delayed union, n (%)	10 (10.0%)	18 (18.0%)	$\chi^2 = 2.67$	OR: 0.51 (0.22-1.18)	0.102
Non-union, n (%)	4 (4.0%)	9 (9.0%)	Fisher's exact test	OR: 0.42 (0.12-1.39)	0.154
Need for secondary procedure (dynamization/bone grafting), n (%)	6 (6.0%)	13 (13.0%)	$\chi^2 = 2.84$	OR: 0.43 (0.16-1.17)	0.092

Table 3 presents the comparison of radiological outcomes between the two groups. The mean time to radiological union was significantly shorter in the suprapatellar group (18.64 ± 3.12 weeks) compared to the infrapatellar group (20.11 ± 3.86 weeks), with a statistically significant difference ($t = 2.98$, $p = 0.003$). Coronal malalignment greater than 5° was observed in 8.0% of patients in the suprapatellar group compared to 19.0% in the infrapatellar group, which was statistically significant ($p = 0.021$).

Similarly, sagittal malalignment was significantly lower in the suprapatellar group (7.0%) compared to the infrapatellar group (17.0%) ($p = 0.030$). The incidence of overall malunion was also significantly reduced in the suprapatellar group

(11.0% vs 24.0%, p = 0.015). Consequently, acceptable alignment was achieved in a significantly higher proportion of patients in the suprapatellar group (89.0%) compared to the infrapatellar group (76.0%) (p = 0.015).
Although delayed union and non-union were less frequent in the suprapatellar group (10.0% vs 18.0% and 4.0% vs 9.0% respectively), these differences were not statistically significant (p > 0.05). Similarly, the requirement for secondary procedures was lower in the suprapatellar group (6.0% vs 13.0%), but did not reach statistical significance (p = 0.092).

TABLE 4. Comparison of complications including anterior knee pain, infection, and non-union between suprapatellar and infrapatellar intramedullary nailing (N = 200)

Complication	Suprapatellar (n=100)	Infrapatellar (n=100)	Test of significance	95% CI	p value
Anterior knee pain, n (%)	15 (15.0%)	31 (31.0%)	$\chi^2 = 7.24$	OR: 0.39 (0.20-0.76)	0.007*
Superficial infection, n (%)	6 (6.0%)	11 (11.0%)	$\chi^2 = 1.58$	OR: 0.51 (0.18-1.45)	0.209
Deep infection, n (%)	3 (3.0%)	7 (7.0%)	Fisher's exact test	OR: 0.41 (0.10-1.66)	0.186
Delayed union, n (%)	10 (10.0%)	18 (18.0%)	$\chi^2 = 2.67$	OR: 0.51 (0.22-1.18)	0.102
Non-union, n (%)	4 (4.0%)	9 (9.0%)	Fisher's exact test	OR: 0.42 (0.12-1.39)	0.154
Implant irritation/prominence, n (%)	5 (5.0%)	13 (13.0%)	$\chi^2 = 3.84$	OR: 0.35 (0.12-1.00)	0.050*
Reoperation required, n (%)	7 (7.0%)	15 (15.0%)	$\chi^2 = 3.27$	OR: 0.43 (0.17-1.09)	0.070
Any complication, n (%)	24 (24.0%)	43 (43.0%)	$\chi^2 = 8.19$	OR: 0.42 (0.23-0.76)	0.004*

Table 4 compares the incidence of complications between the suprapatellar and infrapatellar groups. Anterior knee pain was significantly lower in the suprapatellar group (15.0%) compared to the infrapatellar group (31.0%), with a statistically significant difference ($\chi^2 = 7.24$, p = 0.007). Superficial and deep infections were less frequent in the suprapatellar group (6.0% vs 11.0% and 3.0% vs 7.0%, respectively), although these differences were not statistically significant (p > 0.05).
Delayed union and non-union were also less common in the suprapatellar group, but the differences did not reach statistical significance. Implant irritation or prominence was significantly lower in the suprapatellar group (5.0%) compared to the infrapatellar group (13.0%) (p = 0.050). Reoperation rates were lower in the suprapatellar group (7.0% vs 15.0%), although this difference was not statistically significant (p = 0.070).
Importantly, the overall complication rate was significantly lower in the suprapatellar group (24.0%) compared to the infrapatellar group (43.0%), which was statistically significant ($\chi^2 = 8.19$, p = 0.004). These findings indicate that the suprapatellar approach is associated with fewer complications, particularly anterior knee pain and overall adverse outcomes.

DISCUSSION

Table 1: The present study demonstrated that the baseline demographic and injury characteristics were comparable between the suprapatellar and infrapatellar groups, ensuring uniformity and minimizing confounding bias. The mean age in the current study (41.82 ± 12.46 vs 42.97 ± 11.88 years, p = 0.504) was similar to that reported by Jones et al.(2014)[1], who observed a mean age of approximately 40 years in proximal tibia fractures. Likewise, Sanders et al.(2014)[2] reported no significant age difference between the two surgical approaches (p > 0.05), supporting the present findings.
The male predominance in both groups (68% vs 71%) is consistent with the epidemiological pattern described by Sun et al.(2016)[3], who reported higher incidence of tibial fractures among males due to high-energy trauma. Similarly, the predominance of road traffic accidents (61% vs 64%) aligns with findings by Chan et al.(2016)[4], where RTA accounted for the majority of cases.
Importantly, operative duration was significantly shorter in the suprapatellar group (88.43 vs 94.16 minutes, p = 0.007), which is in agreement with Franke et al.(2016)[5], who reported reduced operative time with the suprapatellar technique due to improved ease of reduction and fluoroscopic visualization. Thus, the comparability of baseline variables strengthens the validity of outcome comparisons in this study.
Table 2: The functional outcomes in the present study were significantly better in the suprapatellar group. The mean Lysholm knee score was significantly higher (86.74 vs 80.93, p < 0.001), which is comparable to findings by Bakhsh et al.(2016)[6], who demonstrated superior

functional scores with the suprapatellar approach (mean difference ~5-7 points, $p < 0.01$). Similarly, improved knee flexion (124.83° vs 118.29°, $p < 0.001$) observed in the present study is supported by Sanders et al.(2014)[2], who reported better range of motion with semi-extended nailing.

Anterior knee pain, a major concern in tibial nailing, was significantly lower in the suprapatellar group (14% vs 29%, $p = 0.010$). This finding is consistent with Zelle et al.(2015)[7], who reported reduced anterior knee pain due to avoidance of patellar tendon splitting. Furthermore, the significantly lower VAS pain scores and earlier return to full weight bearing (10.42 vs 11.63 weeks, $p < 0.001$) align with Morandi et al.(2010)[8], who observed faster rehabilitation in suprapatellar nailing.

The higher proportion of excellent/good outcomes (84% vs 71%, $p = 0.026$) further reinforces that the suprapatellar technique provides superior functional recovery, likely due to better fracture alignment and reduced soft tissue disruption.

Table 3: Radiological outcomes in the present study strongly favored the suprapatellar approach. The time to radiological union was significantly shorter (18.64 vs 20.11 weeks, $p = 0.003$), which is comparable to findings by Bakhsh et al.(2016)[6], who reported earlier union in the suprapatellar group due to improved fracture stability and alignment.

Malalignment rates were significantly lower in the suprapatellar group, both in coronal (8% vs 19%, $p = 0.021$) and sagittal planes (7% vs 17%, $p = 0.030$). These findings are in agreement with Jones et al.(2014)[1], who emphasized that the semi-extended position reduces deforming forces and improves alignment. Similarly, Franke et al.(2016)[5] reported significantly lower malalignment rates with suprapatellar nailing ($p < 0.05$).

The incidence of malunion was also significantly reduced (11% vs 24%, $p = 0.015$), and acceptable alignment was achieved more frequently (89% vs 76%, $p = 0.015$), which is consistent with Avilucea et al.(2016)[9]. Although delayed union and non-union were lower in the suprapatellar group, the differences were not statistically significant, similar to observations by Obremskey et al.(2016)[10].

Table 4: The complication profile in the present study demonstrated a clear advantage of the suprapatellar approach. Anterior knee pain was significantly lower (15% vs 31%, $p = 0.007$), which is consistent with Zelle et al.(2015)[7], who attributed this to avoidance of infrapatellar tendon injury.

Although superficial and deep infection rates were lower in the suprapatellar group, the differences were not statistically significant, similar to findings by Chan et al.(2016)[4], who reported comparable infection rates between techniques. Delayed union and non-union rates were also lower but not significant, aligning with Bakhsh et al.(2016)[6].

Implant irritation was significantly lower in the suprapatellar group (5% vs 13%, $p = 0.050$), which may be due to less soft tissue disruption. The overall complication rate was significantly lower in the suprapatellar group (24% vs 43%, $p = 0.004$), supporting findings by Franke et al.(2016)[5], who reported reduced overall complications with the suprapatellar approach.

CONCLUSION

The present comparative cross-sectional study evaluated the functional and radiological outcomes of proximal tibia fractures managed by suprapatellar versus infrapatellar intramedullary nailing in 200 patients. The findings of this study demonstrate that the suprapatellar approach offers significant advantages over the conventional infrapatellar technique.

Functionally, patients treated with suprapatellar nailing showed significantly better outcomes, including higher Lysholm knee scores, improved knee flexion, reduced pain scores, and earlier return to full weight-bearing. Additionally, the incidence of anterior knee pain, a commonly reported complication in tibial nailing, was significantly lower in the suprapatellar group, indicating better patient comfort and quality of life.

Radiologically, the suprapatellar approach was associated with superior outcomes, including earlier fracture union and significantly reduced rates of coronal and sagittal malalignment, as well as malunion. The semi-extended position used in the suprapatellar technique likely contributes to improved fracture reduction and alignment by minimizing deforming forces and facilitating better intraoperative visualization.

Furthermore, the overall complication rate was significantly lower in the suprapatellar group, particularly with respect to anterior knee pain and implant-related issues. Although infection rates and non-union rates were lower in the suprapatellar group, these differences were not statistically significant.

In conclusion, suprapatellar intramedullary nailing is a safe, effective, and superior alternative to infrapatellar nailing for the management of proximal tibia fractures. It provides better functional recovery, improved radiological alignment, and fewer complications. Therefore, the suprapatellar approach can be considered the preferred technique for intramedullary nailing in proximal tibial fractures in appropriately selected patients.

LIMITATIONS OF THE STUDY

1. The study was conducted at a single tertiary care center, which may limit the generalizability of the findings.
2. The study design was cross-sectional; hence long-term outcomes such as post-traumatic osteoarthritis and cartilage damage could not be assessed.
3. The follow-up period was limited, which may not fully capture late complications such as implant failure or degenerative changes.
4. Randomization was not performed, which may introduce selection bias in allocation of surgical technique.
5. Surgeon expertise and learning curve differences between techniques were not controlled, which could influence operative outcomes.
6. Subjective assessment tools such as pain scores and functional scores may introduce observer or reporting bias.
7. The study did not include advanced imaging modalities (e.g., MRI) to evaluate intra-articular cartilage damage in the suprapatellar approach.
8. Confounding factors such as rehabilitation compliance, comorbidities, and nutritional status were not extensively analyzed.

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