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Case Series

Does the suprapatellar nailing technique address the issue of malunion in segmental tibial fractures?

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ABSTRACT

Background: Segmental tibia fractures are caused by high-velocity trauma. They are often associated with soft tissue and other systemic injuries leading to higher complications rates. In this study, we aimed to analyse the clinical, functional and radiological outcome including the incidence of malunion in these fracture following suprapatellar nailing.

Materials and Methods: We retrospectively analysed 55 patients from January 2016 to January 2020 who underwent suprapatellar nailing using two different nailing systems at a single tertiary care trauma centre. Periodic follow-ups were done to evaluate the union rates, the functionality of the limb and associated complications like malunion.

Result: Average time of union overall was 26 weeks with closed fractures healing at an average of 22 weeks and open fractures healing at an average of 33 weeks. The average functional score using LEFS at the end of one year was 86% with 89% of the patients having good to excellent functional outcome. We had 22 cases of the delayed union out of which only 5 cases required secondary procedures to aid in the union. Malalignment was noted in 1 case. All fractures included in this study eventually healed at the final follow up. Anterior knee pain was reported in 3.6% of the cases.

Conclusion: We recommend suprapatellar nailing in all segmental tibial fractures irrespective of the type of injury as it reduced the rate of malunion and anterior knee pain, without compromising on union rates and functional outcome.

1. Introduction

Segmental fractures of the tibia are usually due to high-velocity injuries seen in young patients[1] and have a relatively high incidence of non-union and malunion due to dynamic forces acting on different fragments and poor healing potential.

Malalignment in segmental tibia fractures is mainly due to deforming forces acting on the proximal fractured fragment, extension force by patellar tendon, medially directed force by guy rope muscles and flexion moment to distal segment by the gastrocnemius muscle. The incidence of malalignment after traditional infrapatellar intramedullary nailing ranges between 58% to 84%.[2,3]

Although numerous treatment options are available, including cast application, intramedullary nailing, external fixation and plate fixation.[4,5] Intramedullary nailing is a particularly desired approach. It enables load sharing while sparing the extraosseous blood supply and avoids major soft tissue dissection. The advent of newer nails with various proximal bends and extra proximal interlocking screw placements for extra axial and rotational stability has broadened the indications for intramedullary nail fixation to more proximal and distal tibia fractures, including the

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proximal metaphyseal region.[6–8]

Traditionally, intramedullary nailing was performed utilizing the infrapatellar technique, which involved splitting/retracting the patellar tendon laterally. Nailing with the knee in a semi extended position has been described by Tornetta et al[9] and an alternative suprapatellar technique in semi extended knee has been described by Morandi et al.[10] & Jakma et al.[11]

Establishing a perfect entry point appears to be crucial while fixing these segmental fractures. The suprapatellar approach allows an ideal entry point and facilitates the reduction of apex anterior deformity of the proximal third fracture fragment in the sagittal plane.

This study analysed the clinical, functional and radiological outcomes of segmental tibial fractures and incidence of malunion when treated with Suprapatellar nailing in patients who presented to our Tertiary Care Trauma Centre. There is a scarcity of literature analysing the outcome of suprapatellar nailing in segmental tibia fractures.

2. Materials and Methods

Patients who underwent suprapatellar nailing for segmental tibial fractures between January 2016 and January 2020 were retrospectively analysed in this study. All patients were followed for a minimum of 1 year and were evaluated for radiological union and functional outcome on a regular interval.

All patients above 18 years of age and with extraarticular segmental tibial fracture were included in this study. Patients with intraarticular fracture extension, other ipsilateral lower limb injuries (excluding fibula fracture), contralateral lower limb injuries, Gustilo Anderson type IIIb and IIIc, and pathological fractures were excluded. Fractures were classified under 42C2 based on AO/OTA and compound fractures were additionally classified according to Gustilo Anderson classification.

All fractures were operated in our level 1 trauma centre in Chennai, India by a dedicated trauma team under the guidance of a single experienced senior trauma surgeon, using reamed intramedullary nailing. Fractures were fixed using either Titanium Expert tibia nail (Synthes) or Trigen meta nail (Smith and Nephew). ETN has 5 locking options proximally and 4 locking options distally with Herzog's bend of 11 degrees and Trigen meta nail has 4 locking options proximally and 3 locking options distally with Herzog's bend of 10 degrees.

2.1. Surgical technique

The standard surgical approach for suprapatellar nailing described in the literature was used with few modifications. The patient was positioned supine on a radiolucent table with the knee in 15-20 degrees of flexion by placing a bump underneath the distal thigh. A midline longitudinal incision was made one finger breadth above the patella. The Quadriceps tendon was split and entry was made into the patellofemoral joint by clearing the patellofemoral soft tissue. The proximal fracture site was reduced using closed manipulation or by percutaneous application of patellar clamp before nail entry or use of poller screw occasionally. A broad sleeve was inserted behind the patella till the anterior edge of the tibial articular surface, thereby protecting the articular cartilage. The entry was made just medial to lateral tibial spine in the coronal plane and at the anterior edge of the tibial articular surface in the sagittal plane using a 3.2 mm drill bit. The entry is made in such a way that the drill bit is parallel to the anterior cortex in the sagittal plane and centre in the coronal plane. The drill bit was replaced with a ball tip guidewire and the wire was advanced in middle and distal fragments after reduction of the distal fragment. The wire was positioned in the centre in both planes distally. Front cutting reamer was used to open the medullary canal. The reduction was maintained throughout the reaming and during nailing. Gentle reaming was done taking appropriate measures to protect the middle segment. After reaming appropriate sized nail was inserted and locked proximally with three screws and distally with two screws. The gap if present at the fracture site was closed either by heel thumping or by the reverse hammering of the nail.

Poller screw or augmentation plating was done in some cases depending on intraoperative assessment for fracture reduction and stability at the proximal fracture site. Although the ETN system is intended for an infrapatellar approach, we have modified the tools to allow for a suprapatellar approach.

2.2. Postoperative protocol

Patients were encouraged to start knee ankle range of motion and quadriceps strengthening exercises postoperatively from day one and were followed up regularly.

Weight-bearing was initiated according to fracture pattern, intraoperative stability and soft tissue status. Partial weight-bearing was started for the patient with axially and rotationally stable fractures immediately after surgery.

Patients were followed after 6 weeks, 3 months, 4.5 months, 6 months, and 1 year for clinical and radiological union and weight-bearing was graded from partial to full weight- bearing status accordingly.

Patients were evaluated at each follow-up functionally using Lower extremity functional scale (LEFS)[12] using a questionnaire-based method (Table 1).

The Radiographic union scale for tibia (RUST)[13] was used to assess union by obtaining AP and lateral view radiographs of the full-length tibia with the knee and ankle joints included. The absence of pain on full weight-bearing,

Table 1: Demographics

	Category	Number
Total Number of Cases		55
Gender	Male	48
	Female	7
Affected side	Right	24
	Left	31
Mode of Injury	RTA	55
		37
Type of Fracture	Closed	18
	compound (3A)	
Fracture pattern	Non-comminuted	23
	Comminuted	32
	Head injuries	10
	Chest injuries	6
	Facial injury	2
	Forearm-	
	I) Ipsilateral	3
	II) Contralateral	2
Other associated injuries	Ipsilateral clavicle	1
	Contralateral	
	Humerus	1
	Ipsilateral	1
	Dislocation	
	I) Shoulder	1
	II) Elbow	1
	Blunt abdomen	1
	Injury	

the lack of tenderness and the absence of abnormal mobility at the fracture site were used to determine clinical union. The term "delayed union" refers to a fracture that took more than 6 months to heal.

2.3. Statistical analysis

Data was analysed using frequency, percentage analysis, mean, standard deviation, using a statistical tool after entering the data into Microsoft Excel and descriptive statistical analysis was done using SPSS version 24, IBM Corp, Chicago. The probability value of 0.05 was considered significant.

3. Result

In our study, 59 patients underwent suprapatellar nailing for segmental tibia fractures. Four patients were lost to follow up, hence we have analysed the records of the remaining 55 patients.

The patients average age was 43.7years (+/- 12 years). The majority of patient's (48 out of 55) were males and the left tibia (31) was more involved than the right (24). RTA was the mode of injury in all cases. Of the 55 fractures, 35 were closed fractures, 2 were closed fractures with impending compartment syndrome, and 18 were compound fractures (IIIA according to Gustilo Anderson classification). 32 had comminution (at either proximal or distal fracture site) and 23 had a non-comminuted fracture (transverse/oblique). Associated head injuries were seen in 10 patients, chest injuries in 6 patients, facial injuries in 2, both bone forearm fractures in 3, elbow and shoulder dislocation in 1 patient each and blunt abdomen injuries in 1 patient (Table 2).

Before surgery, all patients were resuscitated following the ATLS protocol, and primary and secondary surveys were completed. All patients underwent standard suprapatellar nailing using ETN system in 35 patients and Trigen meta nail system in the remaining 20 patients.

Two (grade 3 a) patients required additional augmentation plating, and two required poller (blocking) screw for stabilization of proximal fragment. Single-incision posterolateral fasciotomy was done for two patients with a closed fracture with compartment syndrome. The average hospital stay was 9.2 days (+/- 2.2 days).

From the time of admission to intramedullary nailing, the average time duration was 20.71(+/- 11) hours. Compound fractures were operated on an average of 10.1(+/-4) hours vs 26.3(+/- 9.9) hours for closed fractures.

The average operation time was 36.27 (+/- 7.6) minutes. (Table 3).

The average period for a radiological union was 26.1(+/-7.8) weeks. In compound fractures, the average time to union was 33.4 (+/-5.7) weeks and in closed fractures, it was 22.1 (=/-5) weeks. In 40 individuals, the distal fracture site healed first. There were 22 delayed unions in total mostly seen in compound fractures (17 patients). 5 of the 22 delayed unions needed additional secondary procedures to aid in the union, while the remaining healed without any intervention.

Of the 5 patients requiring secondary procedure, 3 were compound fracture and 2 were closed fracture. Primary single incision posterolateral fasciotomy had been performed on both these closed fractures to release the compartment. As the healing in these fractures was inadequate, bone grafting was performed in these fractures at the end of 6 months. Additional anti-rotation plating was performed because of rotational instability at the proximal fracture site which was observed intraoperatively in 2 cases. All 5 fractures eventually united with the average time for union being 36.8 (+/-1) weeks.

Our results shows that out of 55 patients 54 patients shows minimal to no malalignment (less than 5 degrees) in sagittal and coronal planes.

1 patient had a 10-degree valgus malalignment. 1 patient with a compound grade 3a fracture developed an infection at 12 weeks. He underwent nail removal and application of a ring fixator. The fracture eventually healed at 36 weeks.

2 patients complained of anterior knee pain post operatively mostly with terminal flexion which was

managed with physiotherapy. In 2 patients, the proximal interlocking screw loosening was seen. Ten patients in the study were found to have shortening of less than 1 cm with no limitation during functional activity. There were no cases with rotational malalignment or non-union in our study.

The rate of union, need of secondary procedure, length of stay and surgical time in cases where Trigen nail was used versus Expert tibia nail were found to be comparable as on statistical analysis, the p-value was insignificant ($p>0.05$). (Table 4)

At 1 year follow-up, the average lower extremity functional scale (LEFS) was 86%.

In 89% of the instances, the LEFS score at one year was good or excellent (Table 5).

Figure 1: Case 1: Knee in extension

Figure 2: Case 2: Knee in flexion

Figure 3: Case 1: Cross legged sitting

Figure 4: Case 1: Squatting

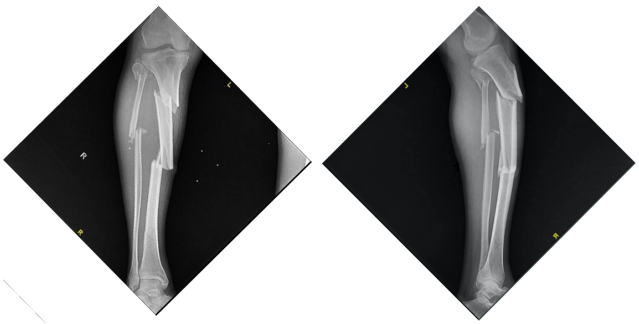

Figure 5: Case 1: Preoperative image ap and lateral view

Table 2: Clinical and radiological outcome

	Category	N
Hospital Stay (In days)	Overall	9(±2.20
	Closed	7.4(±0.7)
	Compound	11.3(±1.9)
Admission to Nailing Time (Hours)	Average	20.7(±11.1)
	Closed	25.8(±9.9)
	Compound	10.2(±4)
Length of proximal fragment		8.7(±2.2)
Length of middle segment		13.7(±5.3)
Lefs (At 1 year)		68.7(±5.9)
Time taken for radiological union (in weeks)	Overall	26.12(±7.8)
	Closed	22.1(±5)
	Compound	33.4(±5.7)
Delayed union	Delayed Union	33.27(±3.7)
	Closed	5
	Compound IIIA	17
Infection		1
Anterior knee pain		2
Screw Loosening		2

Table 3: Comparison between trigen and experttibia nailing

Types of nail		Union time (weeks)	Secondary procedure	Union time (weeks)	Duration of surgery (MIN)	Malunion
Expert tibia nail (35 patients)	Closed (22)	21.4	1	12 weeks	37.3	Valgus 10 Degrees- 1
	Compound (13)	32.9	1	14 weeks		
Trigen meta nail (20 patients)	Closed (15)	23.2	1	12 weeks	34	Nil
	Compound (5)	34	2	14 weeks and 12 weeks		

Table 4: Functional outcome using LEFS score

LEFS	Grade	N	Percent
71-80	Excellent	26	47.27
61—70	Good	23	41.81
51-60	Fair	5	9
<50	Poor	1	1.8

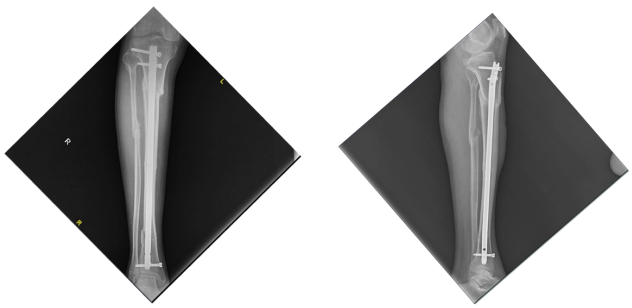

Figure 6: Case 1: Follow up x-ray- 6 months

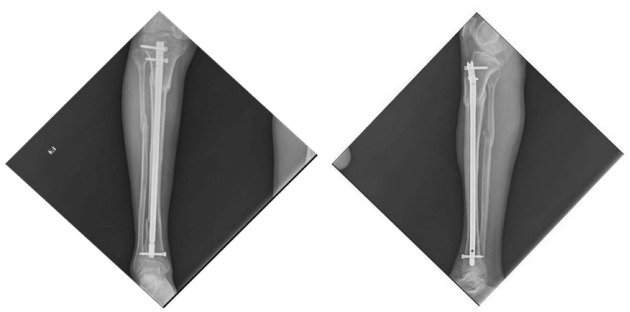

Figure 7: Case 1: Follow op x-ray- one year

Table 5: Rate of malunion in proximal third tibial fractures

Study series	No of cases	Clinical Outcome	Radiological Malalignment
Lang et al[3] 1995	32 Infrapatellar	NA	Coronal plane- 27 Sagittal plane -7
Freedman et al[14] 1995	12 Infrapatellar	NA	Sagittal plane- 7
Torentta and Collins[9] 1996	25 Infrapatellar in semi extended		Coronal plane - 2 Sagittal plane- 0
Vidyadhara and Sarath et al[15] 2006	45 cases infrapatellar in semi extended position		Coronal plane- 3 Sagittal plane- 4
M.S. Kulkarni et al[16] 2020	43 Suprapatellar	LEFS- 89% Union – 7.3 months	Coronal plane- 1 Sagittal plane- 3
Present study	55 Suprapatellar	LEFS– 86% Union – 6.5 months	Coronal plane- 1

Table 6: Comparison with other studies

Study series	Number of cases	Union (in weeks)	Radiological malalignment	Complications
Robert M Corey et al[17] 2017 (RTN)	108	26	Malunion- 6%	Delayed union -40% Non union 10%
Tornetta et al[9] 2007 (UTN)	51	Compound -25.4 Closed- 20	Malunion- 6%	Non union-9%
Giannoudis et al[4] 2002 (infrapatellar)	27 (18 Compound, 9 Closed)	41.4	Malunion- 7%	Non union-4.1%
Our study	55 (18 Compound, 37 Closed)	Closed-21 weeks Compound -34 weeks	Malunion- 2%	Delayed union-40% Non union-0%

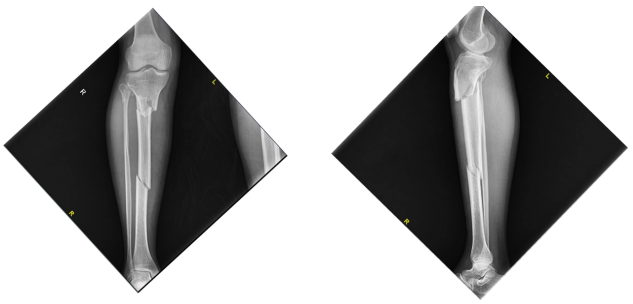

Figure 8: Case 2: Preoperative radiographs AP/ lateral

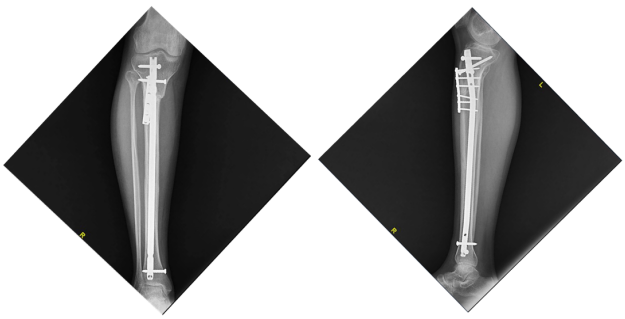

Figure 9: Case 2: Follow up x-ray-6 months

4. Discussion

Our study aimed to see how functional and radiological outcomes improved in extraarticular tibial segmental fractures treated with suprapatellar reamed nailing. Before considering surgical intervention, individuals with segmental fractures require adequate resuscitation and multiple secondary surveys to address other associated injuries.

Anatomical alignment must be restored for the limb to resume its normal function. Due to the already compromised soft tissue in these fractures, open reduction and internal fixation is linked with a significant soft-tissue complication rate. These segmental fractures often have periosteal stripping, further restricting the blood supply of the affected segment resulting in delayed/non-union.[18]

According to a study by Hoon sung Sohn et al.,[19] soft tissue complications can be minimized with bridge plating

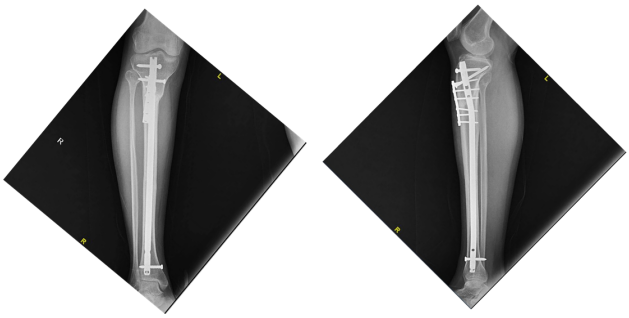

Figure 10: Case 2: Follow up x-ray- 1 year

methods (MIPO), however, the patient with compound fractures need temporary stabilisation using external fixator for soft tissue healing prior to MIPO which prolongs the overall hospital stay and increases the treatment cost. Also, correct anatomical alignment is difficult to achieve with MIPO and chances of malalignment are high at the proximal fracture site, especially at metadiaphyseal junction.

Intramedullary nailing as per treatment methodology to treat segmental fractures of the tibia and proximal tibia fractures is well documented. In our series, the proximal fracture line was usually seen in the metaphyseal or metadiaphyseal region. The average length of the proximal fragment was 8.7 (5-11cm) cm, and the shortest length was 5 cm from the joint line. The average length of the middle segment was 13.73 cm when measured from the proximal fracture line, the longest being 28 cm. Suprapatellar nailing is preferable when the proximal fracture line lies within $1/3^{rd}$ of the total length of the tibia as the infrapatellar approach is more difficult and results in anterior angulation of the proximal segment due to quadriceps pull.

According to Freedman and Lang,[2,3] the traditional infrapatellar technique has a significant rate of malunion, loss of reduction and other complications.

Various techniques have been devised to reduce malunion like perfect entry point (medial to lateral tibial spine), nailing in semi extended position using parapatellar entry after subluxation the patella, suprapatellar nailing after dividing quadriceps tendon. Nailing in semi extended position reduces the pull of the quadriceps thereby reducing anterior angulation of the proximal fragment. It is advised to reduce the fracture before reaming and maintain the reduction during and after the nailing for which use of percutaneous clamp, blocking screw, augmentation plating is advocated in the study done by Daniel J Stinner[20] in 2014.

The modern nails with short Herzog's bend and multiple locking options with angle stable locking screws in the proximal fragments are also helpful in these fractures as they prevent loss of reduction postoperatively and thus malalignment.

When compared to infrapatellar nailing where the knee is kept in hyperflexion, in suprapatellar nailing the knee is kept in semi extended position this leads to better alignment of the fracture and our rates of malunion was only 2% when compared to 6 to 7% in literature (Table 6). We did not encounter any sagittal plane deformity in our study. We believe that this is due to the more accurate entry point with suprapatellar nailing technique compared to infra patellar nailing technique. In our study we had one patient with 10 degree valgus malalignment this patient had significant comminution at proximal fracture site which has contributed to the malalignment.

As all the fractures in our study underwent reamed intramedullary nailing, we could achieve snuggly fitting 3 points bony contact, which reduces the chances of malalignment and non-union at the distal fracture site.

In other studies of segmental tibial fractures treated with reamed intramedullary nailing, delayed distal fracture fragment union was reported due to diminished vascularity of the intermediate fragment due to reaming.[21,22] However, we found that in our study the delayed union was more prevalent in the proximal fracture fragment, as Juxta articular fractures tend to be inherently unstable due to mismatch between the intramedullary diameter, strong quadriceps pull on the fractured fragment and improper fit of the nail.

Also in suprapatellar nailing, since it is relatively easy to reduce and maintain the reduction we were able to perform these surgeries with an average of 37 min, thereby reducing the operative time and stress on the patient which becomes important in polytrauma.

Using this approach not only malalignment was addressed but also the incidence of anterior knee pain was also significantly less when compared to studies using the infrapatellar approach for similar fracture patterns as described by Roy Sander et al[23] and Serbest et al.[24] In another study done by Jarmo et al[25] in 2002 he found that 67% patients complained of anterior knee pain following trans tendinous approach for IM nailing and 71% developed knee pain with the paratendinous approach.

Suprapatellar approach is an equally effective way for treating compound fractures as well. Patients with compound injuries (grade 3A), were initial resuscitated and stabilized using ATLS protocol. Patients were taken to the theatre for thorough wound debridement followed by intramedullary nailing using a suprapatellar approach and primary wound closure was done. 3^{rd} generation cephalosporins antibiotics were started prophylactically and was changed based on culture and sensitivity. Using suprapatellar nailing we were able to minimize the soft-tissue handling, thus preserving the blood supply to the segmental fragment. The closed nature of the procedure and minimally invasive approach further decreases the time of surgery, perioperative blood loss and reduces the chances of infection, thus promoting healing at the fracture site. Also, patients compliance, mobilization and overall rehabilitation

becomes easier after nailing. It is also an economical option as it reduces the duration of hospital stay.

The functional outcome using LEFS Score was excellent in 89% of our cases at the end of one-year follow-up, with patients able to do their regular activities without much discomfort.

We did not find any statically significant difference between the two nailing systems (ETN vs Trigen meta nail) used in terms of time for union, need of secondary procedure and surgical duration.

Overall functional results, radiological union and complication rates are comparable to other studies.

5. Limitation

Some of the limitations of the study are, it's a retrospective study with no control group, it's a non-comparative study with short term follow-up and a small sample size. As all the cases were operated on and analysed by the same team of doctors observer bias can't be excluded.

6. Conclusion

In conclusion, our is the first study to document the radiological and functional result of using the suprapatellar nailing technique in segmental tibial fractures. The rate of malunion was significantly reduced when compared to the other available treatment options. Incidence of anterior knee pain was very less with the suprapatellar approach. This technique can be employed in both closed and compound segmental tibial fractures. If meticulously planned and properly executed good overall functional and radiological outcome can be achieved.

Thus, we recommend suprapatellar nailing in all extra-articular segmental fractures of the tibia irrespective of the fracture line and length of middle segment and nature of injury whether closed or compound.

7. Abbreviation

ETN- expert tibia nail. LEFS- lower extremity functional scale. RUST- radiological union scale for tibia. RTA- road traffic accident, ATLS- advanced trauma life support. MIPO- Minimally invasive plate osteosynthesis.

8. Source of Funding

None.

9. Conflict of Interest

None.

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