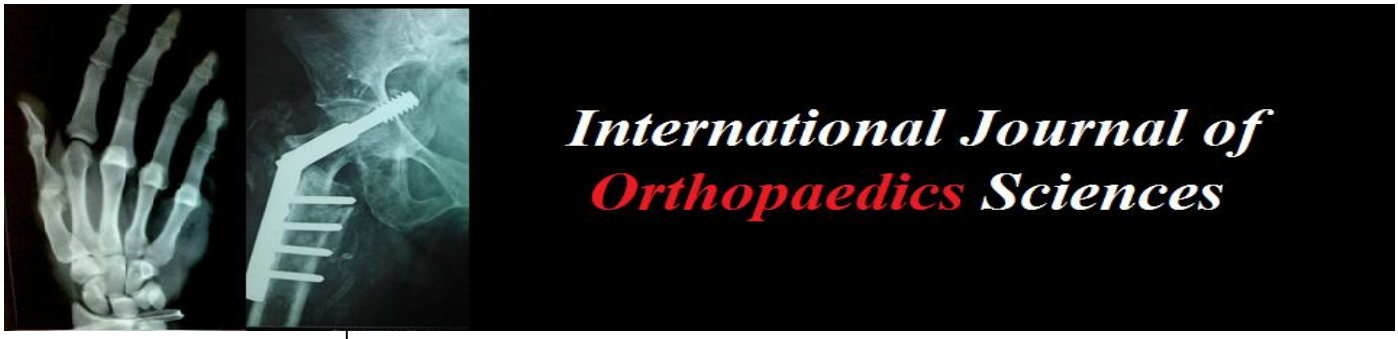

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Pandurangaiah Srinivas
Assistant Professor, Department of Orthopaedics, Sri Devaraj Urs Medical College, Tamaka, Kolar, Karnataka, India

Shaikh B Nazeer
Professor and Unit Head (Ex H.O.D), Unit 3, Department of Orthopaedics, Sri Devaraj Urs Medical College, Tamaka, Kolar, Karnataka, India

Correspondence
Shaikh B Nazeer
Professor and Unit Head (Ex H.O.D), Unit 3, Department of Orthopaedics, Sri Devaraj Urs Medical College, Tamaka, Kolar, Karnataka, India

Analysis of primary interlocking nailing for open fractures of tibial shaft

Pandurangaiah Srinivas and Shaikh B Nazeer

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Abstract
Background: The results of closed intramedullary nailing technique are excellent for treating fractures of the tibial shaft. Court Brown reported that the time to union and infection rates were similar when open tibial fractures were treated by reamed locked intramedullary nail or an external fixator. But references regarding the results, incidence of infection, nonunion related to the specific type of open injuryare limited. Hence we decided to analyse primary interlocking nailing for open tibial fractures.
Materials & Methods: All patients with open tibial fractures treated with primary interlocking nail were evaluated. Wound debridement and nailing were performed with image intensifier guidance. Static or dynamic locking was done depending upon the fracture stability.
Results: 44 patients with 44 fractures were included in the study. 15 (34%) type I, 19 (43%) type II, 9 (20%) type IIIA, 1 type IIIB open fractures were treated. Reaming was done in 41 (93%) patients. Nine (20%) of the nails were dynamically locked. 95% united uneventfully except two (5%). The average time to union was 26 weeks for type I fractures, 29 weeks for type II, 34 weeks for type IIIA, 38 weeks for the type IIIB. There were three deep infections (7%).
Conclusions: Primary Interlocking nailing for tibial open fractures is an excellent mode of therapy. Interlocking nailing reduces the incidence of complications like infection (7%), nonunion (5%). It is more acceptable to patients than external fixators.

Keywords: Tibia, Open Fractures, Primary Nailing

1. Introduction
Tibial shaft fractures 4 cm distal to the tibial tuberosity to 4 cm proximal to the ankle may be treated with interlocking techniques [1]. The results of this technique are excellent for treating fractures of the tibial shaft [2-6]. Gustilo [7] and colleagues found the outcome differences in the subtypes with an infection rate of 4% in type III A, 52% in III B and 42% in III C. Court Brown [2, 3] reported that the time to union and infection rates were similar when open tibial fractures of type II, III A and III B were treated by reamed locked intramedullary nail or an external fixator. Bone *et al.* [8] reported good results after closed primary interlocking in open tibial fractures. Keating *et al.* [5] in their study of open fractures of the tibia found no significant differences results whether interlocking nailing was reamed or not in all Type I, II, III A and B. However the limitations to this technique is its association with higher prevalence of rates of infection. Fisher and associates [9] have noted an increased success rate and lower infection and non union rates with early application of soft tissue free flap coverage compared with delayed coverage. But references which specifically mention the indications, the methods and the results are limited. References are scanty regarding the incidence of infection / nonunion related to the specific type of open injury [8]. Hence we decided to analyse primary interlocking nailing for open fractures of tibial shaft.

2. Materials and Methods
All patients with open fractures of the tibial shaft treated with primary Interlocking Nail between September 2001 to August 2008 were evaluated for inclusion in the present study. Approval from the Hospital Ethics Committee was obtained before the study was begun, and the patients gave informed consent. Inclusion criteria: 1. All grades of open fractures of the tibial shaft were considered for the study except Type III C.

2. All those patients who had a follow up of minimum of one year. Exclusion criteria: 1. Fracture in the proximal end of the tibia or a fracture within four centimeters of the ankle, neither of which was adjudged not to be amenable to interlocking nailing. 2. If the patients had significant medical or surgical disorders to minimise their influence on fracture healing 3. If they had open growth plates.

The data of the patients were recorded as per the AO guidelines. After the initial clinical assessment, all patients began receiving cefotaxime and amikacin. All of the operative procedures were performed by, or under the direct supervision of the consultants. Wound debridement and nailing were performed as soon as possible after admission to the hospital. The wound was closed primarily if there was no severe contamination or severe soft tissue injury. If it was left open, other options like Superficial split thickness grafting after 1 or 2 weeks, or Flap coverage if the bone or tendons were exposed were done.The sequence of management was 1. Wound debridement with or without closure. 2. Fixation of fracture by Primary interlocking nailing. 3. Wound management with SSG, delayed primary closure, Flap, etc at a later date.

Operative Technique: Interlocking nailing: A separate trolley was used for the debridement, after debridement the limb was repainted and redraped. The patient was positioned on an operating table with knee in neutral position. A 3 cm midline longitudinal incision over the patellar ligament was done. A medial paratendinous approach was used to gain access to the intramedullary canal. The canal was broached with a large bone awl, the point of entry being proximal to the insertion of the ligamentum patellae and below the joint line. We did closed reduction and maintained it by applying sterile esmarch tourniquet at the fracture site which prevented fracture displacement. Then guide rod was passed, and negotiated through the fracture site to reach the distal end. This was also done with the knee in neutral position. If it was difficult, we have done it with the conventional knee flexed position. Intramedullary position was confirmed using C-arm images (Fig 1).

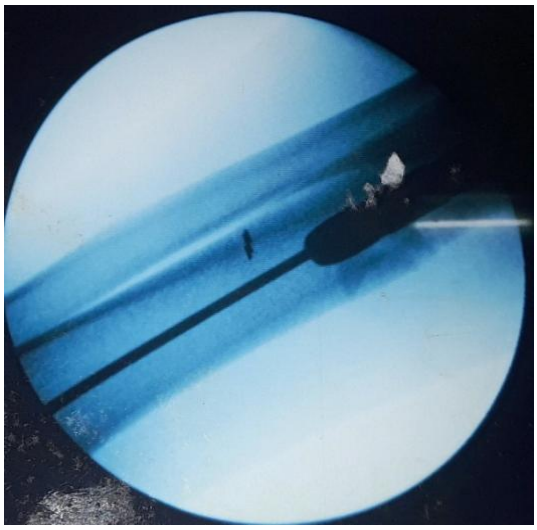

Fig 1

Reaming was done with an electric reamer. The decision regarding the size of the diameter of the nail was made intraoperatively on the basis of the size of the reamer that first made cortical contact at the isthmus of the medullary canal. We attempted the reaming procedure with the knee in neutral, if it was difficult, we have successfully done with the knee in flexion. All the fractures were stabilized with a standard interlocking nail. Then the nail that has the correct length and diameter was inserted by pushing with or without gentle hammering. The decision to perform static or dynamic was now made depending upon the fracture stability. After this the proximal locking was done with the help of the jig. Single or double distal locking was done, again depending on the requirement for fracture stability.

Early perioperative complications including compartment syndrome, fat embolism, and pulmonary embolism were recorded if any. Patients were advised to remain on partial weight bearing for first six weeks irrespective of their fracture configuration. After discharge we examined the patients clinically and radiographically at 6 wks, 12 weeks, 18 weeks, 6 months, 9 months and 1 year. Home exercises were taught to all the patients. None of the patients were referred to physiotherapy department. Clinical union was defined as the ability to bear full weight with no pain at the site of the fracture and radiographic union was defined as evidence of bridging of three of the four cortices on standard anteroposterior and lateral radiographs [5]. We defined nonunion as motion at the site of the fracture on manipulation and no evidence of healing as seen on roentgenograms that were made six months after injury [10]. The fracture was converted to a dynamic status at 12 weeks [11] with removal of the locking screws from the longer segment. The ranges of motion of the knee and ankle were recorded for each patient. It was designated as normal or reduced at the time of the most recent follow up examination. The prevalence of pain in the knee and the necessity for the removal of the implant were also recorded.

The assessment made by the patient was recorded in four groups into excellent, good, fair and poor based on: 1. The final functional outcome, 2. Duration required to return to occupation and 3. Persistance of pain. The surgeons assessment was done as shown in Table No.1; Ekeland *et al.* [4]. When possible, the most recent follow up evaluation was performed for the study.

Table 1: Surgeons Assessment of Final Outcome of fractures. [4] Ekeland *et al.*

	Excellent	**Good**	**Fair**	**Poor**
I. Malalignment				
1. Varus or valgus	5	10	15	>15
2. Antecurvatum or Recurvatum	5	10	15	>15
3. Internal rotation	5	10	15	>15
4. External rotation	10	15	20	>20
5. Shortening	1 cm	2 cm	3 cm	>3 cm
II. Range of knee Motion				
1. Flexion	> 120	120	90	<90
2.Extension deficit	5	10	15	>15
III. Range of ankle motion				
1. Dorsiflexion	>20	20	10	<10
2. Plantarflexion	>30	30	20	<20
IV. Pain	None	sporadic	significant	severe
V. Swelling	None	minor	significant	severe
VI. Duration for Union				
1. Gustilo Type I Open #	<20 wks	21-24	25-28	>28 wks
2. Type II	<24 wks	25-28	29-32	>32 wks
3. Type III A	<28 wks	29-32	33-36	>36 wks
4. Type III B	<32 wks	33-36	37-40	>40 wks

3. Results

Finally 44 patients with 44 fractures were included in the study. The average age of 38 male (86%) and 6 female patients was 33 years (range 18 to 80 years). 23 (52%) of the patients had right sided fractures. The mechanism of injury was RTA in 32 (73%) patients, Domestic in 9 (20%) patients and Industrial in 3 (7%) patients. Among the fractures treated 8 (18%) involved the proximal third of the tibia, 20 (45%) at the middle third, 9 (20%) at the lower third, 7 (15%) segmental fractures. 15 (34%) type I, 19 (43%) type II, 9 (20%) type III A, 1 (2%) type III B Gustilo open fractures were treated. The average duration of time between injury and nailing was 6 hours (range 2 hours to 8 days). 41 (93%) of fractures were fixed after reaming, 3 (7%) without reaming. 10 (23%) nine mm nails, 30 (68%) ten mm nails and 4 (9%) eleven mm nails were used. Nine (20%) of the nails were dynamically locked. Four (9%) wounds were not closed by primary suturing. Local flap cover was used in one (2%) patient and split thickness skin graft was used for 2 (4%) fractures. 1 (2%) was treated with delayed primary closure. All united (95%) uneventfully except two (5%). The average duration of hospitalisation was 11.86 days (range 8 to 25 days). Fig 2a and 2b shows full range of motion achieved during followup after union.

Fig 2a

Fig 2b

The average union time was 29.02 weeks among all the patients of our study (Fig 3a, 3b, 3c, 4a, 4b, 4c).

Fig 3a

Fig 3b

Fig 3c

Fig 4a

Fig 4b

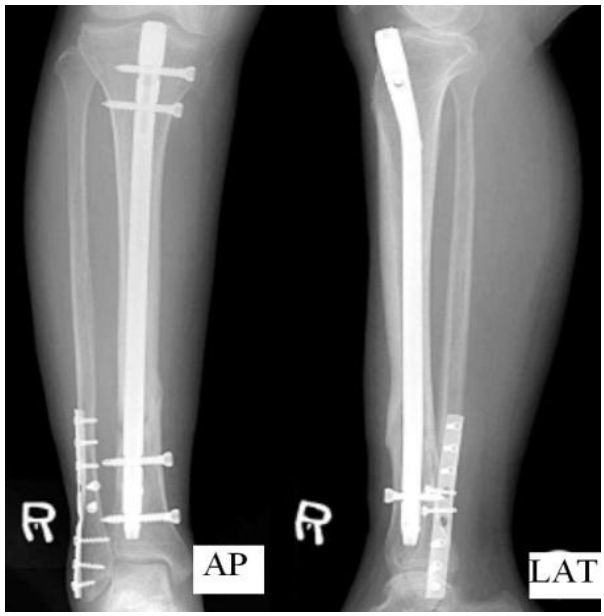

Fig 4c

The average time to union was 26 weeks for type I fractures, 29 weeks for type II fractures, 34 weeks for type III A fractures, 38 weeks for the type III B fracture. The three types of open fractures were analyzed using ANOVA, which showed p value = 0.0198 being significant (<0.05), thus type I having early union than other types is statistically significant in our study. Statistical evaluation was done using SPSS software and Open Epi; considering values like mean, standard deviation, standard error, p value, chi square, ANOVA, Confidence intervals etc.

There were 2 nonunions (5%) (both Type II), both of them had middle third fractures, for one of them exchange nailing with a larger diameter nail with reaming and cancellous bone grafting was done, the donor site being the upper end of the contralateral tibia. The other nonunion patient which was infected was treated with removal of the nail, thorough washing with hydrogen peroxide and betadine solution, freshening of the fracture ends, fibular resection and Ilizarov frame application this united later at about 105 weeks.

There were three deep infections (7%). Two developed in Type II fractures and the other in Type III A fracture. One patient in type II group developed cellulitis after 3 months and had a purulent discharge, which grew staphylococcus on culture. The patient was managed with cephalosporins and repeated dressings. The infection resolved and fracture united in 38 weeks. Another patient (Type II) developed nonunion, was treated with nail removal, fibular resection and Ilizarov frame as stated previously. In the third patient infection subsided with antibiotics and conservative treatment and union occurred.

There was malunion in two patients (5%) and both were in the middle third of tibial shaft. One healed in 7 degrees of valgus angulation and the other had 5 degrees varus and 10 degrees of external rotation and 1 cm of shortening. Both the patients did not require a corrective operation.

The range of motion of knee was decreased in three patients (7%). In the patient with type III A fracture the range of motion was 10 degree flexion to full flexion (FFD 10^0), two (5%) other patients had 10 degree and 15 degree loss of terminal flexion. The range of motion at the ankle was reduced in 5 patients (11%), four (9%) had restricted dorsiflexion of 15 degrees and the plantarflexion was reduced by 20 degrees. The other patient had only limited dorsiflexion of 10 degrees. Based on the patients' assessment we had no poor results, one (2%) fair, three (7%) good and forty (91%) excellent results. As per the surgeons assessment among the 44 patients, one (2%) had a poor result, four (9%) were grouped under the good result heading and thirty nine (89%) under excellent. 15 (32%) patients had pain in the knee, in 10 (21%) of them it subsided in 4 months. In the other 5 (11%) the pain subsided after 4 months however none of the 15 (32%) patients necessitated nail removal.

4. Discussion

Table 2: The following tables depict the results of our study and other studies. Table No. 2 & 3.

Study	Average Age (years)	Range (years)	Sex M:F % M	Total no. of patients	RTA	Middle third	Oblique pattern	Duration from injury to nailing		10 mm dia nail
								Average	Range	
Present	33	18 – 80	38:6 (86%M)	44	32 (73%)	20 (45%)	24 (54%)	6 hrs	2 hrs – 8 days	30
Keating *et al.* [5]	37	16 – 88	77:14 (85% M)	91	63 (69%)	36 (40%)	49 (54%)	9.5 hrs	3.43 – 28.75 hrs	19
Singer *et al.* [11]	36	--	30:11 (73% M)	41	32 (78%)	--	--	5.6 hrs	-	38
Whittle *et al.* [12]	34	17 – 69	34:13 (72% M)	47	41 (87%)	27 (57%)	--	7.5 hrs for W.D., For ILN <8 hrs-25#, 8-13 hrs – 17#, 4-21 days – 8 #		13
Court Brown *et al.* [3]	39.1	17 – 89	31:8 (80% M)	39	26 (67%)	16 (41%)	--	--	--	--
Bone and Johnson *et al.* [5]	31	14 – 77	90:20 (81% M)	110 (26 open #, ILN)	99 (90%)	60 (54%)	--	--	--	--

Table 3: Comparing the results of our study with other studies

Study	reamed	Static	SSG	Flap
Present	41 (93%)	35 (80%)	2	1
Keating *et al.*[5]	50 (55%)	91 (100%)	9	1
Singer *et al.*[11]	--	41 (100%)	-	-
Whittle *et al.*[12]	0	46 (98%)	4	1
Court Brown *et al.*[3]	39 (100%)	39 (100%)	--	2
Bone and Johnson *et al.*[5]	--	82 (75%) GK nail	--	--

Reamed nailing allows larger diameter nail to be inserted. Templemann and colleagues [13] converted nonreamed interlocking nails to reamed nails in 28 tibial fractures. All the results of our study are similar to that of other studies.

Table 4: Comparing incidences of open fractures in all the studies

Study	Gustilo type of open fracture				
	Type I	II	III A	III B	Total
Present	15 (34%)	19 (44%)	9 (20%)	1 (2%)	44
Keating *et al.*[5]	14 (15%)	34 (37%)	35 (38%)	8 (9%)	91
Singer *et al.*[11]	6 (15%)	11 (27%)	16 (39%)	8 (19%)	41
Whittle *et al.*[12]	3 (7%)	13 (28%)	22 (47%)	9 (18%)	47
Court Brown *et al.*[3]	-	14 (36%)	14 (36%)	11 (28%)	39
Bone and Johnson *et al.*[5]	Type I and II – 25 (96%)		Type III A and B – 1 (4%)		26

Union: The % of union, the average time to union of various open fracture (Gustilo classification) types in the present study as well as other studies has been tabulated below. The results of our study are similar to other studies described in the Table No. 5.

Table 5: shows duration of union compared to other studies

Study	Union					
	%	Number	Type I	II	III A	III B
Present	95	42	26 wks	29	34	38
Keating *et al.* [5]	91	85	28-reamed 21-unreamed	28 27	34 31	30 35
Singer *et al.* [11]	89	37	19	28	31	24
Whittle *et al.* [12]	92	43	Average 7 months			
Court Brown *et al.* [3]	-	-	-	23.5	27.2	50.1
Bone and Johnson *et al.* [5]	110 cases included closed and open #s, Average time to union-19 wks, for PrimaryILN-17.8 wks, sec. ILN-21.6 wks					

The average union time in our study was 29.02 weeks. The union time was 36.7 weeks in the study by Court Brown *et al.* [14] Union occurred between 34.2 weeks (Karlstrom and Olerud) [15] and 38.1 weeks (Chan *et al.*) [16]. All three had used external fixators for open fractures of tibia. So nailing gives better union rates than external fixators.

In our study nonunion rate was 5%. Table No.5 compares nonunion with other studies. Kimmel [17] treated 27 open tibial fractures with the Hoffman external fixator and obtained an 87% union rate. In Rommens [18] study with external fixators, pseudarthrosis developed in 13%, which shows that Nailing can provide lesser nonunion rates than external fixation for open fractures of tibia.

Table 6: comparison of nonunion data with other studies

Study	Nonunion					
	%	No.	Type I	II	III A	III B
Present	5	2	0	2	0	0
Keating *et al.* [5]	9	9	1	3	3	2
Singer *et al.* [11]	2	1	1	0	0	0
Whittle *et al.* [12]	8	4	--	--	--	--
Court Brown *et al.* [3]	--	--	--	1	--	--

In our study infection rate was 7%. Table No. 6 shows comparison with other studies. Court Brown *et al.* [14] who used external fixators for open tibial fractures had infection rates of 17.6%. Caudle and Stern [10] had a 24.1% infection rate where all were managed with external fixators. Chan *et al.* [16] documented 38% infection rate who also used external fixators in all their patients. Hence nailing can give low infection rates.

Table 7: showing comparison of infection with other studies

Study	Infection						
	No.	%	Type I	II	III A	III B	Nonunion
Present	3	7%	0	2	1	0	1
Keating *et al.* [5]	2	4%	0	1	0	1	1
Singer *et al.* [11]	5	12	1	1	1	2	-
Whittle *et al.* [12]	4	8%	0	0	1	3	0
Court Brown *et al.* [3]	4	11%	-	1	0	3	-
Bone and Johnson *et al.* [5]	7	6%	Cannot compare as it included closed and open fractures				

In our study malunion rate was 5%. Kimmel [17] had a 39% malunion rate with external fixators. Chan *et al.* [16] documented a 41% incidence of malunion and 62.5% incidence of joint stiffness. This shows that nailing can give better alignment of limb.

As per the surgeons assessment we had 39 excellent results i.e., 89% of patients which can be considered satisfactory. This could not be compared with the similar studies like Keating *et al.*, Singer *et al.*, Whittle *et al.*, Court Brown *et al.* and Bone *et al.* since it was not available in the literature.

The strengths of our study are that we have done some modifications in the surgical technique and treatment protocol which can be practiced by all with ease. 1. Debridement was done first before nailing and separate trolley, drapes and instruments were used for nailing. 2. We aimed at primary closure and due to the excellent debridement protocol we could do primary closure in 40 (91%) of our patients. 3. In all the patients we have not split / damaged the patellar tendon, but retracted it medially. 4. We have tried passing the guide wire and flexible reamer with the knee in neutral position in all the patients. In some of those, where it was difficult, we have flexed the knee. (Fig 5).

Fig 5

5. We have applied a sterile esmarch tourniquet at the fracture site to help in reduction and also maintain reduction of the fracture, in all our patients. (Fig 6).

Fig 6

6. We have not referred any patient to physiotherapy department. Instead we have taught home exercises to all and we have got excellent results in range of motion.

5. Conclusion

Primary Interlocking Intramedullary nailing for open fractures of the tibial shaft is an excellent mode of therapy. Intramedullary locking nailing reduces the incidence of complications like infection (7% in our series), nonunion (5%), malunion (5%) which are acceptable. It is more acceptable to patients than external fixators and wound management is better and easier. Primary nailing provides early stabilization of fracture and thereby helps early soft tissue healing and early rehabilitation. Hence we recommend the following protocol to our readers that wound debridement with or without closure along with primary interlocking nailing should be done for open fractures of the tibial shaft (from group I upto group IIIA of Gustilo classification). At a later date, SSG or flap or delayed primary closure, etc should be done.

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