Unreamed intramedullary nailing in distal tibial fractures

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Abstract

Purpose Unreamed nailing has gained acceptance in the treatment of diaphyseal long bone fractures, especially in cases with polytrauma or high-energy injuries. Its application in distal tibial fractures, however, remains controversial.

Methods In this study, 101 distal tibial fractures treated using closed unreamed nailing were reviewed after a mean follow-up of 32 months. There were 59 type A and 42 type B fractures. The most common fracture pattern was the A1 spiral fracture ($n = 40$) followed by the B2 wedge fracture ($n = 18$). Intra-articular extension was encountered in 14 cases. One-fourth of the patients ($n = 24$) had open injuries. Forty-seven patients had additional injuries, and nearly one-third of them were polytraumatised.

Results Union occurred after a mean time of 23.9 (range, 11–134) weeks. There were 13 cases of delayed union and seven non-unions; all healed eventually with additional surgery in only six fractures. Malunion was seen in 12 cases (five valgus, two varus and five external torsion), ten of which were associated with unplated fibular fractures. Three fractures (two open) were treated for deep infection. The most common complication seen was fatigue failure of the locking screws (27 cases).

Conclusions Unreamed nailing of distal tibial fractures is associated with a rather high rate of bone healing complications and locking screw failure. The decision for its use in the notoriously challenging fractures of this segment should be critically considered.

Introduction

Despite continuous improvements in trauma surgery, the optimum treatment of distal tibial fractures remains controversial. Such fractures are inherently unstable, commonly associated with soft tissue injuries and are associated with a high complication rate including malunion, non-union, wound healing problems and infection [1–4]. Wide open reduction and internal fixation (ORIF) replaced the traditional non-operative treatment of these injuries in the late 1960s. Reviewing the results of ORIF has demonstrated a high risk of soft tissue complications including chronic infection [4–8]. External fixation has gained popularity in treating open fractures since the 1980s but as a definitive treatment has been frequently associated with impaired bone healing and pin site problems [4, 9].

Intramedullary nailing has revolutionised the treatment of diaphyseal long bone fractures, and, in the past few decades, has gained universal popularity. Its advantages include stable fixation, early mobilisation and soft tissues preservation with easier patient care, particularly with multiple injuries [10–12]. New locking facilities have made stabilising non-isthmic fractures possible without interference fitting [4, 13, 14]. Moreover, unreamed nailing, by preserving the endosteum, has been shown to be advantageous in polytrauma patients and in decreasing the incidence of infection in high-energy fractures [10–12]. Initial enthusiasm, however, was later followed by contradictory reports showing a relatively higher rate of delayed union, implant failure and reoperations after its widespread use [2, 15, 16]. This is further complicated in distal tibial fractures for biomechanical reasons which gave rise to a doubt about the wisdom of the general concept of favourable biological conditions such as minimal

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invasiveness and preservation of the intramedullary blood supply if adequate mechanical stability is missing [17, 18].

This study reviews the results of treating distal third tibial fractures using unreamed nails at the author's institution as regards time to union, bone and soft tissue healing complications, implant failure and malunion rate.

Materials and methods

This retrospective cohort study included 101 displaced unstable fractures of the distal tibial third (subisthmic diaphysis and distal metaphysis with or without articular extension) treated using unreamed nailing. There were 66 men and 35 women (male: female ratio, 1.9:1) with a mean age of 39.9 (range, 16–89) years. Fifty-eight patients were treated for a right-sided fracture and 43 for a left tibial fracture. The most frequent cause of injury was road traffic accidents (motor vehicle, motorcycle and pedestrian accidents), responsible for 37 fractures. Thirty-three fractures were caused by low-energy falls. Eleven patients fractured their legs during sport activities (football, bicycling, skiing or inline skating). Direct trauma at work or by falling objects caused an additional 11 fractures. The remaining nine patients fell from a height of more than three metres.

Using the AO/ASIF classification of long bone fractures, 40 fractures were defined as type A1, seven as type A2, 12 as type A3, 14 as type B1, 18 as type B2 and ten as type B3. According to Winquist et al. classification [19], there were 34 fractures without comminution, 31 type-I (minimal comminution), 23 type-II (with at least 50 % cortical contact) and 13 type-III (>50 % comminution) fractures. Twenty patients had no associated soft tissue injury. Fifty-seven fractures had closed soft tissue injury: 38 G-I, 17 G-II and two G-III injuries according to Tscherne and Gotzen [20]. Open fractures were seen in 24 cases. These were classified using Gustilo et al. criteria [21] into 14 type I, seven type II and three type III fractures. Forty-seven patients had additional injuries, nearly one-third of which (17 cases) were polytrauma patients. The most common associated injury was head trauma (11 cases). Only ten fractures occurred with an intact fibula. Intra-articular extension with a Volkmann's triangle fracture (posterior malleolar fragment) was seen in 14 cases.

Nailing was done within a few hours of injury, if other injuries and the soft tissue condition permitted, after a single-shot antibiotic prophylaxis. In 24 patients, however, a delay between one day and several weeks (mean, 16.8 days) took place, mostly because of a concomitant high-grade soft tissue injury obliging a temporary external fixation. All open fractures were treated by immediate irrigation and debridement. If needed, wounds were revised at 48-hour intervals with or without vacuum-assisted closure (VAC) until a

secondary suture was possible or a definitive coverage was done. An immediate perifibular fasciotomy was done in patients presenting with an impending or evident compartment syndrome.

All fractures were reduced by a closed technique under fluoroscopic control on a radiolucent operating table without traction. All nails used were AO Unreamed Tibial Nails (UTN®, Synthes GmbH, Umkirch, Germany). Half the nails were 9-mm UTN®s. The 8-mm UTN® was used in 39 fractures and the 10-mm UTN® was implanted in the remaining 12 patients. Nail length varied between 255 mm and 420 mm. Nails were introduced centrally in the distal tibia with the tip situated at the physal scar. Plate and screws fixation of the associated fibular fracture was performed through a lateral or a posterolateral incision in 11 out of 91 cases. Volkmann's triangle fractures were fixed percutaneously using small fragment lag screws.

Proximal locking was done using the aiming arm mount on the insertion handle. Distal locking was almost always done "free-hand" with a radiolucent drive. A 3.2-mm drill bit was used for the 3.9-mm locking screws (UTN® diameter 8 and 9 mm) whereas a 4.0-mm drill bit was used for the 4.9-mm screws (10-mm UTN®). A dynamic locking mode (using the slot hole for proximal locking) was done in eight fractures. The remainder of the nails were statically locked with two proximal and two to three distal locking screws. Forty static nails were not dynamised. Operative dynamisation was done in 20 nails. Autodynamisation through fatigue failure of the locking screws occurred in 27 fractures. No information about dynamisation was available in six patients.

Union was defined radiologically as the presence of mature bridging callus in three or more cortices seen in biplanar radiography without fracture site pain on unsupported weight bearing. Delayed union was diagnosed at 26 weeks and non-union at 39 weeks, whether an intervention was needed or not. Malunion described fractures healed in >5° angulation in the frontal plane (varus/valgus), >10° angulation in the sagittal plane (procurvatum/recurvatum), torsional deformity greater than 10°, or a shortening more than one centimetre. Statistical assessment was accomplished using the SAS software (SAS Institute, Cary, NC). A *p*-value <0.05 was considered significant.

Results

Three cases were lost to follow-up and six had incomplete records or radiographs. A polytrauma patient with a grade II open fracture developed adult respiratory distress syndrome (ARDS) with fever, leucocytosis, and circulatory failure. Wound revision was done and the UTN® was finally removed 16 days after nailing with intramedullary reaming

and external fixation. Early nail removal because of malreduction was done in a B3 fracture with progressive valgus malalignment (10°) necessitating plate ORIF after 11 weeks. An alcoholic patient with an open B2 (Winquist III) fracture broke his nail four months after insertion due to extreme non-compliance.

Mean time to union for the remaining 89 fractures was 23.9 (range, 11–134) weeks (Fig. 1). Delayed union (DU) occurred in 13 (14 %) cases and non-union (NU) in seven (8 %) fractures (1 A1, 2 A3, 2 B2, and 2 B3). Six of the seven cases who developed non-union were male patients who sustained a high-energy injury and five had open fractures. Delayed and non-union were significantly higher in patients with open fractures ($p=0.037$) and with over 50 % cortical comminution ($p=0.003$). Surgical intervention to enhance union, apart from dynamisation, was done in six cases: three iliac crest bone grafting (ICBG), two exchange nailing using a reamed tibial nail (RTN[®]) and one case of plating with fibulectomy and ICBG. The rest united without additional procedures. When cases with NU were excluded, the time to union averaged 19.7 weeks. Nails were removed after a mean of 20 months. The mean follow-up period for all fractures was 32 months.

Deep infection, defined as culture positive swabs around the bone with or without osteomyelitis, occurred in three fractures (two open). Two of them had septic nail loosening and backed-out distal locking screws, one with ankle joint penetration. Both cases were treated by nail removal, intramedullary reaming and external fixation. The third was an alcoholic patient with a type III open fracture that united without surgical intervention but with chronic osteomyelitis and malalignment. Ten years later, he presented with a refracture after a quarrel that healed after closed reduction and external fixation.

Early revision of the distal locking screws (without nail removal) was done eight to 14 days postoperatively in two

patients nailed in excessive external rotation. Final malunion was encountered in 12 fractures (13 %). Isolated torsional malunion (documented using CT scans) occurred in five fractures (three A1 and two A3), all of which had external rotation deformity ranging between 12 and 24 (mean, 18) degrees. Corrective derotation osteotomy and fixation with a RTN[®] was done in one patient who also had a DU and achieved union in sound alignment. Valgus malunion occurred in five patients (one A3, one B1, one B2, two B3) and ranged between 6 and 12 (mean 8.8) degrees; one of them also had 1.5-cm tibial shortening. Corrective osteotomy and plate fixation was done in one case. Septic nail loosening in an A1 fracture with grade II closed soft tissue injury resulted in 8° of varus collapse and recurvatum. Lastly, one fracture had a complex malalignment of 10° varus with 10° recurvatum and 20° external rotation. Corrective osteotomy with reamed tibial nailing was done after 16 weeks. No other patients with malunion were operated upon because they were either asymptomatic or refused corrective procedures.

As regards the effect of fibular fixation, isolated tibial fractures united after a mean time of 17.5 weeks in comparison to 24.4 weeks for cases with plate fixation of associated fibular fractures and 25 weeks for unplated fibular fractures, respectively. As for fracture alignment, ten out of the 12 cases with malunion had an unplated fibular fracture. These differences were, however, not statistically significant.

The most common complication by far in this study was fatigue failure of the locking screws, seen in 27 (30 %) cases. Its risk increased drastically if union did not occur within 15 weeks after nailing (85 % of screw failures occurred after this time). Screw breakage allows secondary spontaneous dynamisation of static nails. Although difficult, broken screws were usually removed fully at the time of nail removal through percutaneous incisions on the contralateral side after pushing the remaining part with a strong pin.

Fig. 1 A spiral distal tibial fracture with intraarticular extension. Complete union after closed reduction and unreamed tibial nailing with static locking using five interlocking bolts and interfragmentary screw fixation of the posterior malleolus

Four patients had fibular nonunion, one following fibulectomy done to promote union and was treated with fibular plating to correct ankle valgus. The rest remained asymptomatic without functional disability. Cross-union between the tibia and fibula was seen in four patients with same level tibial and fibular fractures. Five patients had mild limitation of ankle dorsiflexion, of these one elderly patient had both anterior ankle impingement and limitation of knee motion. He was managed by arthroscopic excision of the ankle osteophyte and open adhesiolysis of the tethered gastrocnemius.

Discussion

Intramedullary nails are considered the treatment of choice for most tibial shaft fractures. Although the case for this technique has been strengthened by the introduction of locking screws to maintain fracture length, alignment and rotation, there are concerns about nail use in distal segment fractures because of several technical limitations that make fracture reduction and stable fixation difficult [2, 22–24]. The long-lever arm, the short segment left for distal locking and the relatively wide metaphysis that can not afford a snug endosteal fit with little nail-cortex contact prohibiting automatic fracture alignment and allowing considerable nail mobility, all can result in a higher rate of malalignment and increased stress on the locking screws with a greater risk of screw failure, nail migration or ankle penetration [2, 23]. This is further complicated by intra-articular extension or ankle instability due to lateral malleolar fractures [22–24]. Such mechanical conditions are less favourable in unreamed nailing where the discrepancy between the nail diameter and the distal medulla is even greater. In a biomechanical study, Duda et al. reported that unreamed nailing of distal tibial defects results in extremely low axial and high shear strain [17]. They concluded that unreamed nailing of distal tibial fractures without additional fragment contact or fibula stabilisation should be carefully considered.

The first report solely dedicated to the use of unreamed nailing in distal tibial fractures was attributed to Richter et al. in 1997 [25]. In their prospective study, 50 fractures of the distal tibial fifth (with articular involvement in 18 cases) were stabilised by unreamed nailing. Union occurred uneventfully in 90 % of fractures without further intervention. They described a 22 % complication rate seen in all patients with distal fractures of the fibula without additional plating. Mosheiff et al. [26] in 1999 described excellent functional results using the AO unreamed tibial nail in 52 fractures, although 42 % of cases (22 fractures) underwent an additional operation to facilitate union with two cases of non-union and nail breakage and two cases of infection (Table 1). On the other hand, a study by the AO centre in Davos analysing tibial fractures in Swiss clinics from 1994 to 1997 showed delayed union in 17 out of 94 cases treated by unreamed nailing that had revision surgery, from which ten were simple distal fractures without severe soft tissue damage or complicating factors [18]. Other authors reported good union with reamed nails in distal tibial fractures despite the technically demanding procedure [13, 14, 22, 24, 27–32]. In a multicentre European study, Attal et al. reported on 91 distal third tibial fractures treated with the Expert tibial nail (ETN®). Delayed union occurred in 10.6 % of the cases followed. Malalignment over 5° was observed in 6.5 % of cases with screw breakage in 3.2 % and one deep infection [30].

The present study represents the largest single-centre report exclusively utilizing unreamed tibial nails (UTN®) in treating distal tibial fractures. The mean time to union for all cases (23.9 weeks) is definitely longer than in several reports on nailing distal tibial fractures with or without reaming who described periods between 14.8 and 21.3 weeks [6–8, 13, 14, 24–30, 33–37]. This is due to the inclusion of patients with delayed and non-union and the low rate of secondary operations done to enhance union. When the healing time for cases with non-union was deducted, the mean time to union dropped to 19.7 weeks. Nevertheless, the rest of the results confirms the rather high rate of complications accompanying unreamed nailing of distal tibial fractures such as early

Table 1 Results of unreamed nailing in distal tibial fractures

Authors	Cases	Age (years)	Time to union (weeks)	DU/NU	MR/MU	FU (months)
Richter et al. [25]	50	43	18.8	3DU, 1NU	3 (shortening)	12.7
Konrath et al. [29] ^a	20	NR	17	1 NU	1 MU	22
Mosheiff et al. [26]	52	NR	15.3	2 NU	0	18.8
Egol et al. [23] ^a	72	42.6	NR	10 DU/NU	4MR/7MU	26.2
Mohammed et al. [40] ^a	65	42	NR	15 NU	NR	22
Present study (2013)	101	39.9	23.9	13 DU/7NU	12 MU	32

DU delayed union, NU non-union, MR malreduction, MU malunion, FU follow-up, NR not reported

^a Studies with both reamed and unreamed tibial nails

Table 2 Comparative studies on reamed nailing vs. plating in distal tibial fractures

Authors	Group	Cases	Age (years)	Time to union (weeks)	DU/NU	MU	FU (months)
Im and Tae [6] (ACE nail, cannulated tibial nail)	Nail	34	42	18	3 NU (9 %)	4 (12 %)	24
	Plate	30	40	20	2 NU (7 %)	0	
Yang et al. [31] (ZMS nail)	Nail	13	48.2	22.6	0	3 (23 %)	33
	Plate	14	54.6	27.8	0	1 (7 %)	
Janssen et al. [7]	Nail	12	40.7	21	0	6 (50 %)	72
	Plate	12	43.3	19	0	2 (17 %)	54
Guo et al. [34]	Nail	44	44.2	17.7	0	0	12
	Plate	41	44.4	17.6	0	0	12
Vallier et al. [32]	Nail	56	38.1	NR	4 NU (7 %)	14 (25 %): 13 early, 1 late	19.9
	Plate	48	38.5	NR	2 NU (4 %)	9 (18 %): 4 early, 5 late	
Mauffrey et al. [33]	Nail	12	50	21.3	1 DU (8 %)	1 (8 %)	12
	Plate	12	33	NR	3 DU (25 %)	0	12
Li et al. [8] (ETN nail)	Nail	23	37	NR	0	3 (13 %)	24.7
	Plate	23	39	23.1	0	1 (4 %)	25.8

DU delayed union, NU non-union, MU malunion, FU follow-up, NR not reported

malreduction, established malunion, delayed and non-union. The rate of malunion after nailing non-pilon distal tibial fractures ranges between 5 and 28.5 % [3, 6, 8, 13, 14, 22–25, 27, 29–33, 35, 36], with one study by Janssen et al. reporting malunion in six of 12 nailing group fractures [7]. Nonunion occurred in 8 % of the fractures in this study. This compares favourably to the reports by Im and Tae [6] and Vallier et al. [32] nailing groups, whereby the rate of delayed and non-union after nailing distal tibial fractures vary between 0 and 23 % in the literature [3, 6, 8, 13, 14, 22–36]. Screw failure remains a common problem with small diameter nails [2, 15, 16]. Although 55 nails were either dynamically locked or dynamised, nail migration into the ankle occurred in only one case of septic nail loosening. This may support early dynamisation in axially stable fractures to avoid delayed union and fatigue failure of the locking screws.

Multiple prospective [6, 32–34] and retrospective [7, 8, 31] studies comparing open plating and locked intramedullary nailing for distal tibial fractures have described similar results as regards infection, secondary procedures, time to union (17–27 weeks) and rate of non-union (0–9 %) for both techniques. Whereas nailing has the advantage of shorter operative duration and reduced wound problems, ORIF can restore alignment better than nailing that was associated with more malunion (Table 2). Similar results were noted by Zelle et al. in a systematic review of 1,125 distal tibial fractures including 489 (43 %) treated by nailing [3]. Comparing plate and nail fixation of distal tibial fractures is beyond the scope of this paper; however, the results presented match favourably to the nailed groups in most of these studies.

Several surgical tricks and design modifications have been described in order to decrease the risk of malreduction, loss of reduction and established malunion in nailing distal

tibial fractures. Poller screws or percutaneously placed successive K-wires help orient the nail in the desired position and prevent it from going where it should not by reducing the metaphyseal space [24, 30, 37]. Shortened nails allow fixation of distal fourth tibial fractures (with or without articular extension) by removing the distal one centimetre of the nail and thereby allowing reliable static nail locking [14, 27, 31]. As regards distal locking, the use of at least two screws, multidirectional distal locking and angle stable interlocking bolts have been shown to decrease screw failure and fracture non-union and help improve biomechanical stability of the nail construct in distal tibial fractures [38–40].

Fibular plating in distal tibial fractures is still a subject of debate. Egol et al. recommended fibular plating whenever nailing is contemplated in distal tibial fractures [23]. Krischan et al. reported good results with this treatment, even if a single distal locking screw was used [35]. Ehlinger et al. reported that the absence of supplemental fibular fixation was the only statistically identifiable risk factor for malalignment and recommended primary fixation of all distal third fibular fractures [24]. On the other hand, Attal et al. found that additional fibular plating led to an eight-fold higher risk for delayed union [30]. If fibular fractures were at the same level, the risk for delayed union was even 14 fold ($p < 0.001$). They concluded that fibular plating does not increase biomechanical stability in suprasyndesmal distal tibial fibular fractures treated with intramedullary nails. It seems that an intact fibula mostly signifies a low-energy stable fracture with a better outcome. In this study, isolated tibial fractures needed a shorter time to union. For cases with associated fibular fractures, fibular plating showed a higher risk of delayed union than in uniplated fractures. On the other

hand, 83 % of cases with malunion had unplated fibular fractures.

This study is limited by its retrospective nature, the lack of a control group and the participation of several surgeons in the nailing procedures over a long time period with different experience level, a fact that was shown by Obremskey and Medina to be significantly influential as regards malunion rates [36].

In conclusion, unreamed nailing of distal tibial fractures is associated with a relatively high complication rate that makes its routine use in this notorious segment unjustifiable. Knowing the challenging biomechanical nature of the distal tibia and its limited soft tissue coverage that makes open fixation modalities rather risky, unreamed nailing may still offer a treatment alternative in terms of closed reduction and biological fixation with a low risk of wound problems in high-energy fractures. The risks and benefits of its use should however be carefully weighed before surgery.

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