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ORIGINAL PAPER

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Treatment of open tibial shaft fractures using tightly fitted interlocking nailing

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Abstract Between 2000 and 2003 we treated 23 patients who sustained open tibial shaft fractures with tightly fitted interlocking intramedullary nailing. There were three grade I, eight grade II, nine grade IIIa, and three grade IIIb open fractures. Nail diameters were decided on using preoperative and intraoperative radiographs. Nails were introduced after gentle passage with a 7- to 8-mm hand reamer. Union was obtained in all cases. Nine (37.5%) fractures, however, required additional procedures before union. Three of them gained union through exchange nailing, bone graft, and bone transport, respectively. The remaining six underwent dynamisation. Two of them required an additional exchange nailing for non-union; thereafter one healed and the other gained union through an additional bone graft. Deep infection occurred in one case. Screw breakage occurred in one case only. Tightly fitted nailing produced a significantly lower incidence of locking screw breakage. However, even with this advantage, this technical modification has failed to show clinical advantage in terms of higher healing rate or lower rate of secondary procedures.

Résumé Entre 2000 et 2003, nous avons traité 23 patients qui présentaient une fracture ouverte de la diaphyse tibiale par clou verrouillé intra médullaire. Il s'agissait de 3 Grades I, de 8 Grades II et de 9 Grades IIIa ainsi que 3 Grades IIIb. Le diamètre du clou a été décidé d'après les radiographies préopératoires, durant l'intervention et en fonction des résultats de la radiographie per-opératoire. Les clous ont été introduits après un passage d'alésoires de 7 à 8 mm. La consolidation a été obtenue dans tous les cas. 9 fractures (37,5%) ont nécessité une procédure additionnelle pour obtenir la consolidation, 3 ont pu être consolidées après le changement de clou avec une greffe ou un transport osseux. Les six patients restant ont nécessité une dynamisation du montage. Deux d'entre-eux ont nécessité un changement de clou pour pseudarthrose. Les deux ont consolidé grâce à une greffe. Nous avons observé une infection profonde dans un cas, des fractures de vis dans un cas. Cette attitude thérapeutique nous semble tout à fait justifiée et présente des avantages pour obtenir une consolidation assez rapide ou tout au moins une consolidation retardée, secondaire assez précoce.

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Introduction

Although there is some controversy concerning the treatment of open tibial shaft fractures of higher than Gustilo-Anderson type IIIb with an intramedullary(IM) nail or an external fixator, it is generally accepted that IM nailing is the mainstay treatment for fractures lower than IIIa [1, 2, 14, 15]. However, some authors advocate a larger diameter nail, since the use of small diameter nails increases the risks of metal breakage and delayed union [5, 9–11]. However, many investigators prefer using unreamed nails based on the theory that reaming causes more endosteal vascular damage and cortical necrosis which in turn increase the risk of infection [3, 4, 8, 14, 16, 18]. Here, we describe our results of treating open tibial shaft fractures with tightly fitted nailing after minimal hand reaming in order to minimize osteonecrosis due to vascular damage, and to avoid metal failures and delayed unions.

Materials and methods

We identified 32 patients with open tibial shaft fractures who had been treated by unreamed nailing during a 3-year period (January 2000 through December 2003) retrospectively. We excluded nine patients who had undergone initial management with external fixation and those who failed to complete the follow-up. We analysed the medical records and radiographs of the remaining 23 patients. This study group included 21 men and two women with an average age of 38.6 years (range: 17–70, Table 1). Four patients had an additional injury of the brain (cases 1, 6, 16, 20), one had injuries of the pelvic bone and humerus (case 2), one had bilateral femur fractures (case 6), and one had an injury of the ipsilateral knee joint. Three patients had a Gustilo-Anderson type I open fracture, eight patients a type II fracture, nine patients a type IIIa fracture, and three patients a type IIIb fracture. Morphological classifications of fractures according to the Orthopaedic Trauma Association (OTA) system were: A1 in two cases, A2 in three, B2 in ten, B3 in four, C1 in one, and C3 in three cases. Most fractures were of the midshaft (18 patients) and there was one proximal shaft fracture and four distal fractures. The most common mechanisms of injury were motor vehicle accidents (20 patients); three fractures resulted from a direct blow.

With the exception of one case that was delayed for 3 days for an associated brain injury, all cases were treated on an emergency basis within an average of 14 h since the initial injury (range: 6–26 h). One surgeon (the senior author) performed débridement in all cases. After débridement, a new sterile drape was used and fractures were treated by unreamed nailing. The patellar tendon was split and a hand reamer with a diameter of 7–8 mm was gently passed into the medullary canal a couple of times. We then inserted a nail 1–2 mm narrower than the isthmic diameter of the contralateral medullary canal. If the nail advanced into the canal without much resistance, a 1-mm larger diameter nail was selected for insertion. IM nails of 9 mm (seven cases), 10 mm (eight cases), 11 mm (five cases), 12 mm (two cases), and 13 mm (one case) were used. Static interlocking screw insertion was the treatment rule, and dynamic double locking was done though a proximal oval hole in six cases in which more than 50% cortical bone contact was obtained at the fracture site. ***All patients were given intravenous antibiotics with cephalosporins and aminoglycosides until soft tissue coverage***. There were three type IIIb fractures. In one of these (case 7, Table 1), reconstructive soft tissue surgery was delayed until 17 days after the index operation because of liver function deterioration. A rotational flap was performed 5 days after the initial injury in another case. In the third case, a medial gastrocnemius muscle flap was used to restore soft tissue defects. In the remainder, exposed bone could be covered with local fascia or soft tissues, and skin lacerations were left open for 2–7 days before closure. In 16 cases the wounds were closed directly at 2–7 days (mean: 4.06 days). In three cases, skin grafting was performed (Table 1).

Evaluation of union and alignment

Bone union was defined as a combination of clinical evidence of the disappearance of pain in the fracture area, ambulation without crutches, and radiographic evidence, both on anteroposterior and lateral views, of more than three bridges of cortical bone by callus. On final follow-up radiographs, more than 5° of angulation was defined as malunion.

Clinical evaluation

Ranges of motion of the ankle and knee were measured.

Results

Bone union

Bone union without any additional procedure was obtained at an average of 5.4 months(range: 4–10 months) in 14 of the 23 cases. In eight cases in which a secondary procedure was necessary for bone union, the time for union was 10.2 months on average (range: 5–16 months). In the remaining one case, bone union was obtained at 9 months with bone transport because of a deep infection (case 18). Of eight cases (cases 1, 2, 5, 7, 13, 14, 15, 17) that needed a secondary procedure for bone union, one case in which early dynamic fixation was performed underwent exchange nailing at 5.5 months and bone union was obtained in 6 months (case 1). Six cases (cases 2, 5, 7, 13, 15, 17) of early static fixation resulting in delayed union underwent dynamisation at 2–5 months and four cases united without further procedure. Two cases that were not united after dynamisation underwent exchange nailing. After exchange, one case united in 5 months (case 17) and the other was diagnosed as non-union because the anterolateral bone defect was not filled with callus, although the posterior cortex was connected with callus formation 6 months after exchange. This defect was filled with graft and bone union was then obtained in 4 months (case 14). In the remaining single case, in which a butterfly fragment of 50% of the bone diameter had been removed, the opposite side of the defect united in 6 months after the index operation, but the defect area did not unite and required a bone graft which united over the following 4 months. There was no angulation of more than 5°. Posterolateral translation by 5 mm was noted in one case (case 10) and shortening by 5 cm was noted in another, in which osteomyelitis had been diagnosed (case 18).

Table 1 Summary of the patients' data

No.	Age	GA	OTA	Nail	Locking	Coverage method (days after index operation)	Additional procedures (months after index operation)	Union time (months after index operation)	Remarks
1	34	IIIa	B2	UTN	Dynamic	STSG (10)	EXN (5.5)	9 (4 after EXN)	Traumatic brain injury
2	37	IIIa	B3	UNTN	Static	DP (6)	Dynamisation (5), EXN (6), BG (12)	16 (4 after BG)	Pelvic bone, humerus shaft fractures
3	40	IIIa	B3	Russel-Taylor	Static	DP (4)		10	
4	28	IIIa	B2	UTN	Dynamic	DP (4)		4	
5	26	IIIa	B2	UNTN	Static	DP (4)	Dynamisation (2)	5	
6	19	IIIa	C3	Russel-Taylor	Dynamic	DP (7)		5	Traumatic brain injury, bilateral femur fractures
7	35	IIIb	B3	UNTN	Static	Latissimus dorsi flap (17)	2nd débridement under general anesthesia (2 days), Dynamisation (2)	14 (12 after dynamisation)	Flap was delayed due to deterioration of liver function, proximal locking screw breakage
8	52	I	A2	UTN	Static	Healing by secondary intension		4	
9	38	II	A1	CTN	Dynamic	DP (4)		4	
10	35	II	B2	UNTN	Static	DP (2)		5	5 mm posterolateral translation
11	17	II	A2	UNTN	Static	DP (4)		4	
12	70	IIIb	C3	UTN	Static	Rotational flap (5)	Loss of reduction at proximal fracture site at 2 months, additional plating	6	Healing of distal open fracture site without further procedures
13	40	IIIa	A1	MDN	Static	STSG (21)	Dynamisation (3)	6	Stiff ankle(0–30°)
14	23	II	B2	UTN	Dynamic	DP (6)	Bone graft (6)	10	
15	26	II	B2	MDN	Static	DP (4)	Dynamisation (3)	6	
16	23	II	B2	UTN	Static	DP (3)		7	Traumatic brain injury, ipsilateral knee subluxation
17	18	IIIa	B3	Ace	Static	DP (3)	Dynamisation (3), EXN (12)	16 (5 after EXN)	Superficial infection, controlled with in travenous antibiotics
18	70	IIIb	C2	UTN	Static	Hemi-gastrocnemius flap (5) after 2 times of repeated débridement under general anesthesia	Nail removal for deep infection (1), acute shortening and Ilizarov fixation, osteotomy and transport (2), bone graft at docking site (6)	9	Shortening of 5 cm, contralateral AK amputation
19	29	IIIa	B2	UNTN	Dynamic	STSG (5)		5	Arthroscopic fibrolysis due to knee stiffness
20	50	II	B2	UTN	Static	DP (5)		6	Traumatic brain injury
21	42	I	C3	CTN	Static	DP (2)		5	
22	41	II	B2	CTN	Static	DP (5)		6	
23	40	I	A2	UTN	Static	DP (2)		4	

GA Gustilo-American classification *OTA* Orthopaedic Trauma Association classification, *UNTN* universal tibial nail (Mathys) *MDN* metaphyseal-diaphyseal nail (Zimmer), *STSG* split thickness skin graft, *DP* delayed primary closure, *EXN* exchange nailing, *BG* bone graft, *CTN* cannulated tibial nail (Mathys)

Implant failure or fixation loss

Interlocking screw breakage was noted in one case (case 7) in which a large diameter IM nail, 12 mm, had been used. The nail was dynamised at 2 months. A screw inserted in the proximal oval locking hole had broken. Despite this metal failure, bone union was obtained 12 months after dynamisation.

Infection

Infection was noted in two cases. One case with a Gustilo-Anderson IIIa fracture was accompanied by an erythematous skin change with serous discharge a month after operation. The infection was resolved by 3 weeks of antibiotic therapy. A 70-year-old polytraumatised patient (case 13) developed deep infection 7 days after soft tissue coverage. The nail was removed, the tibia was shortened by 6 cm in order to close the soft tissue defect, and the fracture was secured using a ring external fixator. Bone union was obtained at 9 months after bone transport with tibial shortening of 5 cm.

Functional result

A restricted range of motion was observed in five cases (cases 1, 7, 13, 16, 18). Two of the five restricted range of motion cases (cases 1, 16) had coexisting brain damage. In the other two cases (cases 7, 18), repeated débridements were inevitable due to severe muscular injuries.

Discussion

Although sporadic reports [9–11] indicate that there is no significant difference between reamed and unreamed nailing for open tibial shaft fractures with regard to infection rate, many orthopedic surgeons remain reluctant to adopt reamed nailing due to concern that the reaming causes more endosteal vascular damage and cortical necrosis [3, 4, 8, 14, 16, 18].

On the other hand, the most crucial drawbacks of unreamed nailing, i.e., a high incidence of locking screw failure and delayed bone union, are considered to arise because of compromised stability at the fracture site due to the use of nails with a relatively small (8–9 mm) diameter [6, 7, 13].

We have also been trying to choose nails that fit the medullary canal as tightly as possible to overcome this shortcoming of unreamed nailing. Preoperative radiographs and intraoperative fluoroscopic assessments are used to

Fig. 1 **a** Initial radiograph showing an AO 42B3 fragmented wedge fracture. **b** Intraoperative picture showing an extensive muscle crushing and degloving injury, which subsequently resulted in a large soft tissue defect. **c** Postoperative radiographs showing fracture fixation with good alignment. **d** Radiographs taken at 14 months after index operation showing solid union with callus bridging. A broken proximal locking screw is also visible. **e** Clinical photograph taken at 14 months showing functional status and soft tissue coverage

measure the diameter of the isthmic portion of the medullary canal precisely, and a nail 1~2 mm narrower than the determined diameter is inserted. To avoid nail impaction within the canal and iatrogenic fracture, a 7- to 8-mm hand reamer is gently passed a couple of times prior to nail insertion. In this way, relatively larger size nails of up to 13 mm can be used according to the medullary canal diameter. All of the nails used in the study had diameters larger than 9 mm, and 16 of the 23 were over 10 mm. We have not experienced intraoperative complications like nail jamming or iatrogenic fracture. Only one of the 57 interlocking screws broke, which is much lower than the breakage rates (10–41%) reported previously [1, 6, 7, 11, 13, 16, 18].

Generally interlocking screw breakages, which may act as a form of "auto-dynamisation," are believed to yield a low rate of malunion [11, 18]. However, Lopez et al. reported five interlocking screw failures among 24 cases (21%), which were associated with shortening of more than 1 cm [13]. This suggests that interlocking screw breakage may play a role in complications such as limb shortening. Also Keating et al. reported that in nine cases of non-union, two were attributed to interlocking screw breakage, and three were potentially related to IM nail failure [11]. Although it is unclear whether failure of interlocking screws leads to non-union, the interlocking screw breakage which is not the intention of the operator should be avoided if possible. The nail insertion technique presented in this study involving a larger IM nail without standard reaming was found to effectively reduce interlocking screw failure (Fig. 1).

Bone union was observed at an average of 5.4 months (range: 4–10 months) in 14 of the 23 cases without additional procedures. However, in eight cases (34.8 %) secondary procedures were necessary due to delayed union; in these cases bone union was obtained in an average of 10.2 months (range: 5–16 months).

There are very limited clinical reports about tightly fitted nailing for open tibial shaft fractures. Lin and Hou reported very satisfactory results of locked tight-fitting nailing on 52 closed and open tibial shaft fractures [12]. Secondary procedures were required to obtain union only in four (15%) of 27 open fractures, but 17 (60%) f 27 fractures were classified as Gustilo type I or II fractures.

In previous publications many authors have reported secondary procedure frequencies of 17–61% [1, 3, 4, 6, 16, 17]. Some authors have recommended early dynamisation or bone graft because of the high proportion of cases requiring secondary procedures to obtain bone union [4, 6, 17]. The wide range of reported differences in the need for additional procedures must be mainly attributed to the diversity of patients studied. In other words, there is a tendency for fractures classified as Gustilo-Anderson type III to require secondary procedures. Our study also included open fractures associated with severe soft tissue defects graded at IIIa (nine cases, 39.1%) and IIIb (three cases, 13%). Thus, bone union rates do not simply depend on the means of fixation but are also closely related to the initial extent of soft tissue damage and the thoroughness of débridement.

It was also reported that tightly fitting IM nails cause more cortical vascular impairment, which suggests that our insertion method can potentially induce cortical vascular damage [8]. However, it is unclear how such theoretical concerns relate to clinical results.

Although we obtained a significantly low incidence of locking screw breakage with the tightly fitted interlocking nailing technique, we have failed to improve the union rate without secondary procedures.

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