Lo SCALPELLO (2021) 35:139-145
doi number: 10.36149/0390-5276-228

The Exchange Reamed Nailing technique in the treatment of aseptic tibial nonunion. A literature review of 371 cases

Alessandro Cerone[1], Pierluigi Mastri[1], Vittorio Calvisi[1], Antonio Medici[2], Andrea Fidanza[1,3]

[1] Department of life, Health & Environmental Sciences, University of L'Aquila, Unit of Orthopaedics and Traumatology, L'Aquila, Italy; [2] Unit of Orthopaedics and Traumatology, "AORN San Giuseppe Moscati", Avellino, Italy; [3] OTODI Young Abruzzo-Molise

Summary

The persistence of pain at the fracture site and the absence of bone callus at X-ray controls are the univocal criteria for diagnosis of nonunion. When this failure befalls, the healing process has stopped and the fracture is no longer able to consolidate without surgery. The aim of this review is to investigate the use and outcomes of the Exchange Reamed Nailing (ERN) technique for aseptic tibial shaft nonunion.

Replacement surgery with an oversized reamed nail showed 91% success. After a tibial fracture, nonunion is to be expected in 17% of cases, with a majority of the hypertrophic type (82%). To avoid further failures, the following is essential: to increase the mechanical stability by implanting an oversize nail and lock it with 2 distal static screws and a proximal dynamic screw; to ream the canal to promote vascularisation with osteoinductive and osteoconductive effects; to ensure the absence of a latent infection, which can lead to osteomyelitis in 18% of failures. Autologous bone grafting and fibula osteotomy are useful in specific cases.

Key words: nonunion, pseudarthrosis, diaphyseal fracture, tibial fracture, intramedullary nailing

Received: January 10, 2022
Accepted: February 7, 2022

Correspondence
Alessandro Cerone
Unit of Orthopaedics and Traumatology, University of L'Aquila, piazzale S. Tommasi 1, 67100 Coppito (AQ), Italy.
E-mail: alessandro.cerone1@graduate.univaq.it

How to cite this article: Cerone A, Mastri P, Calvisi V, et al. The Exchange Reamed Nailing technique in the treatment of aseptic tibial nonunion. A literature review of 371 cases. Lo Scalpello Journal 2021;35:139-145. https://doi.org/10.36149/0390-5276-228

Introduction

Non-healing of a fracture may manifest itself as a delayed-union, defined as a fracture that does not heal within the expected time (referring to the type and location of the fracture and the patient's characteristics), or even as a nonunion, in which the healing process has stopped and the fracture is no longer able to consolidate without surgery [1].

There is no agreement about the different timing in the definition of non-union, and for some authors it can be considered after 4 months from the trauma [2-5], for others no earlier than 6 months [6-10]. The persistence of pain at the fracture point and the absence of bone callus in at least three of the four corticals visible in two projections at X-ray controls are the univocal criteria for the diagnosis of nonunion [11].

The factors that can induce aseptic nonunion can be summarised as follows: 1) poor reduction of the fracture; 2) low synthesis stability; 3) reduced vascularisation at the fracture site; 4) bone loss [1,11].

Despite the progress of surgical techniques and the improvements in hardware, the incidence of non-union and mal-union in diaphyseal tibial fractures reaches almost 17%, which is also due to the frequent exposure of the fracture and poor skin coverage [12-14]. There are several surgical techniques used to heal a nonunion of the tibia in case of failure of the first treatment. The Exchange Reamed Nailing (ERN) is a technique that involves removal of the first intramedullary implant and its replacement with an oversized nail with canal reaming, in order to provide greater stability of the synthesis (Fig. 1).
The purpose of the current narrative review is to define the reliability, technique and outcome of aseptic nonunion of the tibial shaft treated with ERN.

Methods

We carried out a review of the English language literature to identify studies where the effectiveness of the ERN was analyzed in terms of percentages and times of consolidation and occurrence of complications. The keyword "exchange reamed nailing" was used in combination with "tibial pseudarthrosis" and "tibial nonunion" on the search engines Google Scholar and PubMed.
Inclusion criteria: patients who developed aseptic nonunion of a previous diaphyseal tibial fracture and were then treated with ERN. Exclusion criteria: non-diaphyseal tibial fractures, diaphyseal fractures of other long bones, septic nonunion or treatments other than ERN.
The characteristics of the sample were extrapolated and compared by analysing the fracture pattern and treatment options, definition of healing, type of nonunion, percentage of patients healed following surgery, average time of consolidation and the number of failures as infections, nonunion and residual malunion. Where data were available, a correlation between failure and fracture pattern was carried out, with reference to any initial open fracture according to the Gustilo-Anderson (GA) classification [15].

Results

Sample description

Only 7 studies met the inclusion criteria for the current review [11,16-21] and involved a total of 370 patients with 371 cases of diaphyseal tibial aseptic nonunion that were surgically treated with ERN.
Of 370 patients, 75 were female, 288 were male and 7 with unspecified gender. Age was available for 336 patients with a mean of 41 years (Tab. I).
Clinical recovery criteria were considered to be full weight bearing without pain [17,18,20,21] and without tenderness [20,21].
The radiographic healing criteria were aimed at identifying the bone callus: presence of callus in three of the four cortical in two projections [18,22,23]; presence of callus in at least 50% of the cortical circumference [17,24]; disappearance of the radiolucent line or bridging callus [19] in two orthogonal projections [20] or with adequate density to band the two fragment [18,20,23].

Figure 1. A) Aseptic hypertrophic tibial nonunion in a 53-year-old man at 8 months post-trauma; B) post ERN control – distal fixation with 2 static screws, proximal fixation with a dynamic locking screw; C) X-ray control at 5 months of follow up – immediate full weight bearing.

For 331 patients the traumatic mechanism of injury was reported: for 70% it results from an accident (9% pedestrian, 27% car- and 34% motorcycle-crash), 15% from falls from a height, 10% from sports injuries and in the remaining 5% by crush injuries and gunshot wounds.
Only 241 fractures were classified according to the AO classification, as follows: 122 fractures 42A; 84 fractures 42B; 35 fractures 42 C (Tab. II).
In 253 cases the type of nonunion was specified, showing that hypertrophic nonunion is more frequent (82%) than atrophic (18%); the definitive diagnosis of nonunion was made on average at 5.5 months.
About half of the patients (49%) had closed fractures, while 10% reported type 1 open fracture according to GA classification, 16% type 2, 17% type 3 and 4% unspecified exposure,

Table I. Demographic characteristics and mechanism of injury of the sample.

	Gender	Mean age	Mechanism of injury					
			Pedestrian accidents	Car-crash	Motorcycle-crash	Falls from height	Sport	other
Hierholzer (2016) [11]	32 f 156 m	43	0	82	54	24	28	0
Templeman (1995) [16]	6 f 21 m	-	10	4	8	2	0	3
Ateschrang (2013) [17]	11 f 14 m	51	4	4	4	7	3	3
Zelle (2004) [18]	10 f 30 m	35.1	9	14	5	7	2	3
Sledge (1989) [19]	7 f 44 m	33	7	13	14	11	0	6
Richmond (2004) [20]	9 f 23 m	43	-	-	-	-	-	-
Kan-Da Gao (2004) [21]	-	-	-	-	-	-	-	-
Total	75 f 288 m	41.14	30	89	113	51	33	15

comprising a total of 175 patients (47%) with open fractures. An emergency fasciotomy was required in 4% of patients due to acute compartment syndrome.
The intramedullary nail appears to be the most common method for treating tibial shaft fractures (81%), of which 32% were performed without canal reaming, while in 68% of cases it was not specified whether reamed or non-reamed tibial nails were used. Other treatments (19%) consisted in external fixation, ORIF and non-operative treatment.

Follow-up and outcomes

Only one patient was lost to follow-up and it was not possible to evaluate healing or complications. In 91% of cases the ERN technique achieved consolidation of the fracture, while in 33 cases (9%) complications occurred or required further surgery to obtain healing (Tab. III).
Regarding complications, infection (chronic osteomyelitis) occurred in 6 cases following revision surgery and malunion was found in 6 additional cases. Infection was defined as the presence of fever, erythema and cultures positive for debridment [16]. Malunion was defined as the presence of deformities in the various planes or shortening. In particular, the presence of a varus or valgus deformity in the frontal plane greater than 5°, an angulation in the sagittal plane in procurvatum or recurvatum greater than 10°, rotational deformities in the coronal plane greater than 15° or a shortening greater than 1 cm compared to the contralateral limb [22,25].

The mean consolidation time was calculated for 343 cases and was found to be 20.64 weeks, with a minimum of 14 and a maximum of 32 weeks.
Only Templeman et al. [16] correlated infections to initial exposure: three post-revision infectious were found inon 27 cases, two occurred in previous open fractures (GA 3b) and one in a patient with compartment syndrome treated with decompressive fasciotomy.

Discussion

Intramedullary reamed nailing with removal of the previous hardware represents an approach that provides widely shared good results in the treatment of nonunion of the tibia with a relatively minimally invasive surgery. Aseptic non-unions are basically divided into two categories in order to implement the correct therapeutic strategy: (1) the types with good vascularisation where the main problem is a poor mechanical stability of the synthesis and in which an improvement of the latter offers a good chance of success; and (2) avascular forms where the need for a biological stimulus and bone grafting coexist [9]. The ERN, or rather the use of an adequately locked and dimensioned intramedullary nail associated with canal reaming, offers good prospects for success in both forms by providing improvement in mechanical stability, improvement in periosteal blood circulation and by acting as an autologous graft [26]. In-fact, the results obtained from the analysis of the current

Table II. Classification of the injury and nonunion.

	AO class	Close *vs* open (GA classification [15])							Nonunion classification		Nonunion timing criteria
		Closed	Closed + compartment syndrome	GA1	GA2	GA3a	GA3b	Unsp	Hypertrophic	Atrophic	Mounths
Hierholzer (2016) [11]	103 42A 62 42B 23 42C	111	0	17	38	22		-	164	24	6 m
Templeman (1995) [16]	12 42A 8 42B 8 42C	3	8	0	5	6	6	-	-	-	3-5 m
Ateschrang (2013) [17]	7 42A 14 42B 4 42C	19	0	4	2	0	0	-	25	0	6 m
Zelle (2004) [18]	-	6	7	4	8	4	11	-	19	21	4 m
Sledge (1989) [19]	-	17	0	14	7	13		-	-	-	4 m
Richmond (2004) [20]	-	21	0	-				11	-	-	6 m
Kan-Da Gao (2004) [21]	-	4	0	-				3	-	-	9 m
Total	122 42A 84 42B 35 42C	181	15	39	60	62		14	208	45	

literature collected in this review show a 91% success deriving from this method.

Improvement in mechanical stability

According to the literature, an oversized nail with adequate locking provides increased stability by favouring the impact of the fracture stumps with fair weight bearing [18,27] and avoiding further angular stress [17,18]. It should also be emphasised the importance of the right choice of locking technique, such as the number, distance and orientation of screws, and whether static or dynamic fixation is performed[2 8].

Promote vascularisation

Reaming has been shown to cause damage to the endosteal vascularity at the focus of the pseudarthrosis for 8-12 weeks [17,29], while the surrounding soft tissues remain unharmed and periosteal vascular flow is stimulated to promote fracture healing [18,30]. In fact, several studies have shown that the direction of blood flow reverses from being centrifugal to centripetal as a result of endosteal damage caused by reaming with up to 6-fold increases in periosteal flow compared to vascularisation of the contralateral unreamed tibia [31]. In addition, from studies conducted on fractured sheep's tibia and subjected or not to reaming, vascular flow in the muscles adjacent to the fracture in the reamed group was increased [11,32].

The osteoinductive and osteoconductive effects

In addition to the effects on vascularisation and the debridement of the canal fibrotic tissue, reaming would also seem to have osteoinductive and osteoconductive effects, depositing a sort of bone graft in the pseudarthrosis site [18,20]. This process can improve the local biology and stimulate bone healing [27] because it contains growth factors and osteoblasts that act as an osteoconductive scaffold.

Technical notes

The surgical technique of all the analyzed reports consisted, first of all, in the removal of the previous hardware, which

Table III. Treatment options and follow-up.

	First treatment options			Consolidation post revision		Mean time of consolidation on weeks	Complication	
	Uspecified intramed-ullary nail	Unreamed intramed-ullary nail	other	Union	Nonunion		Infection	Malunion
Hierholzer (2016) [11]	188	0	0	165	23	16	0	0
Templeman (1995) [16]	0	28	0	25	2	-	3	3
Ateschrang (2013) [17]	0	25	0	24	1	29	0	0
Zelle (2004) [18]	0	40	0	38	2	29	0	0
Sledge (1989) [19]	3	3	45	49	2	28	3	3
Richmond (2004) [20]	8	0	24	29	3	14	0	0
Kan-Da Gao (2004) [21]	7	0	0	7	0	32	0	0
Total	206	96	69	337	33	20,6	6	6

were mostly intramedullary nails (302 of 371). Subsequently, any deformities present were corrected and the intramedullary guide wire was repositioned, positioning it in the center of the distal canal, and verifying it in at least two intraoperative radiographic projections. The reaming and subsequent implanting of the oversized intramedullary nail was then carried out. Mechanically, reaming was used to position a nail with a good cortical fit at the isthmus level, using drill diameters 1 or 2 mm larger than the nail. If the implanted nail replaced a previous nail, it had a diameter of 1 or 2 mm larger than the previous one. If the implanted nail replaced other hardware, the goal was to insert a nail of at least 10 mm in diameter with an average of 11-13 mm, depending on the surgeon and the study. Locking is also an important check: there is no agreement among studies, but all authors agree on fixation of the distal fragment with at least 2 locking screws. Regarding the proximal fragment, a dynamic locking screw was preferred for transverse or short oblique fractures in order to improve stress of the fragments.

In addition to the surgical nailing technique, the use of autologous or substitute bone grafts and fibula osteotomy has also been observed. Bone graft seems to be necessary in the presence of comminuted fractures and extensive bone loss [7,33], defined as > 30% of cortical diameter [34,35].

At the same time, it is hard to find consensus for the indication for fibular osteotomy [36-38]. It should be practiced where earlier healing or the absence of fibula's fracture does not allow a good reduction, thus preventing restoration of length, correction of angular tibia deformities and compression of the nonunion site to create a mechanical block and hinder dynamisation and micro-stresses related to early loading that are necessary for proper restorative osteogenesis [39-41].

Infection prevention

From analysis of predicting factors for infective complications, it emerged that GA 3b open fractures have a higher risk of incurring infections. To prevent this risk, careful clinical-laboratory screening should be carried out to exclude a silent infection on clinical signs (i.e. fever, signs of superficial infection at the exposure site or from previous surgical injury such as dehiscence, fistulas and secretions) and laboratory examinations and tests [18,36].

Limits

The main limitation of current narrative review is the limited number of cases present in the literature and the lack of homogeneity among studies in terms of patient selection, data collection and outcomes analysed.

Conclusions

The high success rate and low onset of complications demonstrate that ERN is an effective and relatively minimally-invasive treatment for aseptic non-union of diaphyseal tibial fractures.

To cope with non-healing of fractures, it is necessary to thoroughly analyse the factors that may have led to failure and plan the revision considering the appropriate size of the new nail, adequate reduction of the fracture avoiding deformities and bone gaps and careful patient selection to rule out silent infections (frequent in ≥ GA 3b). In addition, it may be useful to combine other measures such as autologous bone grafting in comminuted fractures with extensive bone loss and fibula osteotomy in cases where the integrity of the fibula hinders the reduction or compacting of the fracture.

Ethical consideration

Ethics Committee or Istitutional Review Board approval or the informed consent are not required for this study because all the data have been pro-cessed and presented as aggregated data. Consequently for all of them it is not possible to identify any individual patient, according with WMA Declaration of Helsinki.

Authors' contributions

Conceptualization: AC, AM and AF; software and statistical analysis: AC; data curation: AC; writing-original draft preparation: AC; writing-review and editing: AC, PM, and AF; supervision: VC and AM. All authors have read and agreed to the published version of the manuscript.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of interest

The Authors declare no conflict of interest.

References

1 McKee MD, Ochsner PE. Pseudartrosi asettica. In: Principi AO per il trattamento delle fratture. Roma: CIC Edizioni Internazionali 2009, pp. 505-518.

2 Clancy GJ, Winqist RA, Hansen ST. Nonunions of the tibia treated with Küntscher intra-medullary nailing. Clin Orthop 1982;167:191-196. https://doi.org/10.1097/00003086-198207000-00029

3 Galpin RD, Veith RG, Hansen ST. Treatment of failures after plating of tibial fractures. J Bone Joint Surg Br 1986;68:1231-1236. https://doi.org/10.2106/00004623-198668080-00013

4 Johnson EE, Marder RA. Open intra-medullary nailing and bone-grafting for nonunion of tibial diaphyseal fracture. J Bone Joint Surg Am 1987;69:375-380. https://doi.org/10.2106/00004623-198769030-00008

5 Moed BR, Watson JT. Intra-medullary nailing of aseptic tibial nonunions without the use of the fracture table. J Orthop Trauma 1995;9:128-134. https://doi.org/10.1097/00005131-199504000-00007

6 Jürgens CH, Wolter D, Queitsch CH, et al. Methods and results in the treatment of aseptic post-traumatic nonunions of femur and tibia. Zentralbl Chir 1995;119:706-713.

7 Oh JK, Bae JH, Oh CW, et al. Treatment of femoral and tibial diaphyseal nonunions using reamed intra-medullary nailing without bone graft. Injury 2008;39:952-959. https://doi.org/10.1016/j.injury.2008.02.024

8 Rüedi TP, Murphey W. AO principles of fracture management. Stuttgart: Thieme 2000.

9 Weber BG, Brunner C. The treatment of non-unions without electrical stimulation. Clin Orthop 1981;161:24-32. https://doi.org/10.1097/00003086-198111000-00005

10 Weber BG, Cech O. Pseudarthrosis. Pathophysiology, biomechanics, therapy, results. Bern: Hans Huber 1976.

11 Hierholzer C, Friederichs J, Glowalla C, et al. Reamed intramedullary exchange nailing in the operative treatment of aseptic tibial shaft nonunion. Int Orthopaedics (SICOT) 2016:1-7. https://doi.org/10.1007/s00264-016-3317-x

12 Attal R, Blauth M. Unreamed intramedullary nailing. Orthopade 2010;39:182-191. https://doi.org/10.1007/s00132-009-1524-5

13 Forster MC, Bruce ASW, Aster AS. Should the tibia be reamed when nailing? Injury 2005;36:439-444. https://doi.org/10.1016/j.injury.2004.09.030

14 Lin J, Hou SM. Unreamed locked tight-fitting nailing for acute tibial fractures. J Orthop Trauma 2001;15:40-46. https://doi.org/10.1097/00005131-200101000-00008

15 Kim PH, Leopold SS. In brief: Gustilo-Anderson classification. [corrected]. Clin Orthop Relat Res 2012;470:3270-3274. https://doi.org/10.1007/s11999-012-2376-6

16 Templeman D, Thomas M, Varecka T, et al. Exchange reamed intramedullary nailing for delayed union and nonunion of the tibia. Clin Orthop 1995;315:169-175. https://doi.org/10.1097/00003086-199506000-00018

17 Ateschrang A, Karavalakis G, Gonser C, et al. Wien Klin Wochenschr. The Central European Journal of Medicine 2013;125:244-253. https://doi.org/10.1007/s00508-013-0355-x

18 Zelle B, Gruen GS, Klatt B, et al. Exchange reamed nailing for aseptic nonunion of the tibia. J Trauma 2004;57:1053-1059. https://doi.org/10.1097/01.TA.0000100380.50031.DC

19 Sledge SL, Johnson KD, Henley MB, et al. Intra-medullary nailing with reaming to treat nonunion of the tibia. J Bone Joint Surg Am 1989;71:1004-1019. https://doi.org/10.2106/00004623-198971070-00007

20 Richmond J. Colleran K, Borens O, et al. Nonunions of the distal tibia treated by reamed intramedullary nailing. J Orthop Trauma 2004;18:603-610. https://doi.org/10.1097/00005131-200410000-00005

21 Ga K-D, Huang J-H, Li Fa, et al. Treatment of aseptic diaphyseal nonunion of the lower extremities with exchange intramedullary nailing and blocking screws without open bone graft. Orthopaedic Surg 2009;1:264-268. https://doi.org/10.1111/j.1757-7861.2009.00041.x

22 Keating JF, O'Brien PJ, Blachut PA, et al. Locking intramedullary nailing with and without reaming for open fractures of the tibial shaft. J Bone Joint Surg Am 1997;79:334-341. https://doi.org/10.2106/00004623-199703000-00003

23 Duwelius PJ, Schmidt AH, Rubinstein RA, et al. Nonreamed interlocked intramedullary tibial nailing. Clin Orthop 1995;315:104-113. https://doi.org/10.1097/00003086-199506000-00011

24 Chen CE, Ko JY, Pan CC. Results of vancomycin impregnated cancellous bone grafting for infected tibial nonunion. Arch Orthop Trauma Surg 2005;125:369-375. https://doi.org/10.1007/s00402-005-0794-6

25 Browner BD, Jupiter JB, Levine AM, et al. Tibial shaft fractures. Skeletal Trauma 1998:2187-2294.

26 Brinker MR, O'Connor DP. Exchange nailing of ununited fractures. J Bone Joint Surg Am 2007;89:177-188. https://doi.org/10.2106/JBJS.F.00742

27 Högel F, Gerber C, Bühren V, et al. Reamed intramedullary nailing of diaphyseal tibial fractures: comparison of compression and non-compression nailing. Eur J Trauma Emerg Surg 2013;39:73-77. https://doi.org/10.1007/s00068-012-0237-3

28 Hoffmann S, Gerber C, Oldenburg G, et al. Effect of angular stability and other locking parameters on the mechanical performance of intramedullary nails. Biomed Tech (Berl) 2015;60:157-164. https://doi.org/10.1515/bmt-2014-0100

29 Schemitsch EH, Kowalski MJ, Swiontkowski MF, et al. Cortical bone blood flow in reamed and undreamed locked intramedullary nailing: a fractured tibia model in sheep. J Orthop Trauma 1994;8:373-382. https://doi.org/10.1097/00005131-199410000-00002

30 Danckwardt-Lilliestrom G. Reaming of the medullary cavity and its effects on diaphyseal bone: a fluorochromic, microangiographic and histologic study on the rabbit tibia and dog femur. Acta Orthop Scand 1969;128(Suppl):1-153. https://doi.org/10.3109/ort.1969.40.suppl-128.01

31 Reichert IL, McCarthy ID, Hughes SP. The acute vascular response to intramedullary reaming. Microsphere estimation of blood flow in the intact ovine tibia. J Bone Joint Surg (Br) 1995;77:490-493. https://doi.org/10.1302/0301-620X.77B3.7744943

32 Schemitsch EH, Kowalski MJ, Swiontkowski MF. Soft-tissue blood flow following reamed versus undreamed locked intramedullary nailing: a fractured sheep tibia model. Ann Plast Surg 1996;36:70-75. https://doi.org/10.1097/00000637-199601000-00014

33 Crowley D, Kanakaris NK, Giannoudis PV. Femoral diaphyseal aseptic non-unions: is there an ideal method of treatment? Injury 2007;38(Suppl 2):S55-S63. https://doi.org/10.1016/S0020-1383(07)80010-6

34 Bone LB, Kassman S, Stegeman P, et al. Prospective study of union rate of open tibial fracture treated with locked, unreamed intramedullary nails. J Orthop Trauma 1994;8:45-49. https://doi.org/10.1097/00005131-199402000-00010

35 Whittle AP, Russell TA, Taylor JC, et al. Treatment of open fractures of the tibia with the use of interlocking nailing without reaming. J. Bone Joint Surg 1992;74A:1162-1171. https://doi.org/10.2106/00004623-199274080-00005

36 Wu CC, Shih CH, Chen WJ, et al. High success rate with exchange nailing to treat a tibial shaft aseptic nonunion. J Orthop Tauma 1999;13:33-38. https://doi.org/10.1097/00005131-199901000-00008

37 Bonnevialle P, Bellumore Y, Foucras L, et al. Tibial fracture with intact fibula treated by reamed nailing. Rev Chir Orthop Reparatrice Appar Mot 2000;86:29-37.

38 Hsiao CW, Wu CC, Su CY, et al. Exchange nailing for aseptic tibial shaft nonunion: emphasis on the influence of a concomitant fibulotomy. Chang Gung Med J 2006;29:283-290.

39 Delee JC, Heckman JD, Lewis A. Partial fibulectomy for ununited fractures of the tibia. J Bone Joint Surg 1981;63-A:1390-1395. https://doi.org/10.2106/00004623-198163090-00004

40 Bone LB, Johnson KD. Treatment of tibial fractures by reaming and intramedullary nailing. J Bone Joint Surg 1986;68-A:877-887. https://doi.org/10.2106/00004623-198668060-00009

41 Reckling FW, Waters CH. Treatment of nonunions of fractures of the tibial diaphysis by posterolateral cortical cancellous bone-grafting. J Bone Joint Surg 1980;62-A:936-941.