Arch Orthop Trauma Surg (2008) 128:833–839
DOI 10.1007/s00402-007-0383-y

TRAUMA SURGERY

# Surgical treatment and outcomes of extraarticular proximal tibial nonunions

**Michael J. Gardner · Jose B. Toro-Arbelaez · Sreevathsa Boraiah · Dean G. Lorich · David L. Helfet**

Received: 5 June 2007 / Published online: 21 June 2007


**Abstract**
*Introduction* Although malunion of proximal tibial metaphyseal fractures are not infrequent, nonunion of the proximal tibia is rare. These nonunions can present particular challenges in management, such as malalignment, a short proximal segment, and soft tissue compromise. Few treatment guidelines and long-term outcomes are available. The purpose of this study was to determine the long-term functional outcomes of patients treated with open reduction and internal fixation.
*Materials and methods* Sixteen patients with a proximal tibial nonunion were treated between 1992 and 2005. Five fractures were originally open injuries, but all were aseptic at the time of definitive fixation. All nonunions were treated with a consistent approach of debridement, deformity correction, lateral plating, tensioning and compression, lag screws and bone grafting. Patients were reviewed radiographically and with a Knee Society questionnaire at a mean follow-up of 39 months (range 10–113 months).
*Results* All nonunions healed at an average of 4 months, and alignment was within 5° of anatomic in all cases. Knee Society function and knee scores improved significantly, to 87.4 and 89.4, respectively ($P < 0.05$ for both). Functional outcomes were excellent overall. Fourteen of the patients (88%) subjectively returned to their previous activities and were satisfied with their result.
*Conclusions* Using an algorithmic approach of débridement, deformity correction, lateral tension band plating with compression, and rigid stabilization, fracture healing and functional outcome can be reliably restored in these difficult fractures.

**Keywords** Proximal tibia · Nonunion · Knee Society Rating Scale · Functional outcomes

M. J. Gardner (✉) · J. B. Toro-Arbelaez · S. Boraiah · D. G. Lorich · D. L. Helfet
Department of Orthopaedic Surgery,
Hospital for Special Surgery, 535 East 70th Street,
New York, NY 10021, USA
e-mail: gardnerm@hss.edu

## Introduction

Failure to achieve bone healing in the proximal tibial metaphysis is rare [2, 21, 24]. Although fractures of the proximal tibia are frequently secondary to high energy accidents, this region is notable for a rich vascular supply and a large cross-sectional area of metabolically active trabecular bone, which usually allows for reliable healing [3, 4].

The majority of studies on proximal tibia fractures have reported nonunion rates between 0 and 3% [1, 2, 5, 9, 18, 21, 24, 25]. When nonunions do develop, however, their management can be especially challenging due to tenuous soft tissues and a short articular segment. In the coronal plane, anterior compartment musculature or an errant starting point frequently leads to valgus angulation, and lateral buttress plates may not control medial collapse when comminution exists, leading to varus deformity. These deformities may be caused by the surgical technique, and may progress subsequently due to poor implant purchase of varying degrees. Traditional implants which have been used to treat proximal tibial fractures may not have been ideal for metaphyseal fixation. Intramedullary nails in particular have had notoriously poor alignment difficulties historically. Many early nails did not have had an appropriate proximal bend, which, coupled with external muscle forces, frequently led to a procurvatum deformity [8, 12, 14, 16]. Henley et al. [12] described the "wedge effect", whereby the nail acts as a wedge when the bend is placed distal to the fracture, which often leads to posterior translation and angulation of the distal segment and is directly related to the diameter of the nail used.

Very little information or guidelines for treating these nonunions are available in the literature. The purpose of this study was to determine the outcomes of patients following surgical intervention with consistent treatment principles.

## Materials and methods

Following approval from the Institutional Review Board, a search was conducted of an orthopaedic trauma service database for all patients treated for proximal tibial nonunions between 1992 and 2005. Inclusion criteria were a diagnosis of a nonunion of the proximal tibial metaphysis, with absence of any signs of healing at 4 months postoperatively. Patients were included whose initial fracture was purely extraarticular (AO/OTA 41-A2, 41-A3) and those who initially had intraarticular involvement (AO/OTA 41-C1, 41-C2, 41-C3) [7] as well as adequate radiographic and clinical follow-up until fracture union.

Sixteen patients met the study criteria and all were included in the analysis. Average age was 45 years (range, 25–62 years), and 11 patients were male. The mechanism of injury in six patients was a motor vehicle accident, in two a motorcycle accident, in two pedestrian struck, in two a fall from a height, and one each had a crush injury, a skiing injury, stress fracture, and iatrogenic from a bone grafting procedure. Five patients originally sustained open fractures, which included 1 Type II, 2 Type IIIA, 1 Type IIIB, and 1 Type IIIC according to the classification of Gustilo and Anderson [10]. Thirteen fractures were classified as AO/OTA Type 41-A, and three patients initially had intraarticular extension and were classified as AO/OTA 41-C types (Table 1). In the patients with C-type injuries, none of the intraarticular fracture components were involved in the nonunion. The initial treatments included nonoperative, rigid IM nails, Ender's nails, external fixation, unicondylar compression and locked plates, and bicondylar plates. The time between injury and diagnosis of the nonunion was 8.7 months on average, and all nonunions were determined to be aseptic at the time of definitive reconstruction based on negative cultures. Fourteen patients had an axis deformity of at least 5° in the coronal plane (normal = 87° varus joint line) or sagittal plane (normal = 9° posterior slope).

All patients underwent surgical treatment with open reduction and internal fixation, débridement of the nonunion, correction of the deformity using indirect and direct techniques, bone grafting, and early supervised active-assisted motion postoperatively. The Knee Society Rating Scale [13] (KSRS) was determined for each patient preoperatively and postoperatively. The two subgroups of this rating scale, the Knee Function and Knee Assessment subscales, were also determined. Statistical comparisons between pre- and postoperative KSRS scores were made using paired Student's $t$ tests, using a significance level of $P < 0.05$.

### Surgical technique

A standardized approach was used to address these nonunions using consistent principles. Prior to the surgical procedure, a careful preoperative plan was constructed. The first consideration was the reason for the healing failure. In many cases, previous treatment with an intramedullary nail in the voluminous proximal tibia had led to a malreduction, limiting the surface area contact of the bone ends, and often creating a mechanically unstable environment. Alternatively, varus collapse often occurred with a lateral plate without medial support or compression. Next, deformity in all planes was determined based on full-length lower extremity radiographs, a scanogram, and/or computed tomography version studies. All potential treatment options were considered based on the specific characteristics of the case, particularly in regard to the status of the soft tissues, and in all cases it was decided that a laterally based plate would be the best approach.

The patient was placed supine on a radiolucent table with a bump under the ipsilateral hip, and a tourniquet was placed on the thigh. Ideally, an anterolateral lazy-S incision was employed. In many instances, it was necessary to use previous incisions, particularly if a midline incision or a rotational or free flap had been used previously. The incision was extended proximal to the knee joint to allow for capsulotomy, and a meticulous arthrolysis with mobilization of the knee joint was performed if preoperative knee motion was limited. The iliotibial band was incised in line with its fibers, which was elevated along with the anterior compartment off of Gerdy's tubercle and the lateral tibial cortex. Any previous hardware was removed, and the nonunion site was exposed. The fracture site was mobilized, and a lamina spreader was placed in the defect. All fibrous and scar tissue around the nonunion was removed, including the entire pseudocapsule. The fibrous covering of the intramedullary spaces on both sides was removed using curettes and drills, which continued until the bone ends were fully mobile and with bleeding bone surfaces. This allowed the ingress of blood and bone marrow products. Autogenous iliac crest bone graft or demineralized bone matrix was then placed at the fracture site.

Deformity correction in all planes, based on the preoperative planning, was considered imperative. If the fibula was intact or healed, consideration was given to fibular osteotomy, particularly in varus deformities. If this was necessary, it was performed by making an oblique osteotomy or

**Table 1** Patient data

| Case # | Fracture Type (AO/OTA) | Initial Treatment | Pre-op deformity | Pre-op ROM | Bone graft type | Time to healing (mos) | LLD (cm) | Follow-up (mos) | Post-op ROM | Pre-op KS function score | Pre-op KS knee score | Post-op KS function score | Post-op KS knee score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 41-C1 | Nonoperative | 5° varus | 0–110 | ICBG | 5 | 1 | 60 | 0–130 | 55 | 67 | 100 | 100 |
| 2 | 41- A2 | Plate | 15° varus, 8° procurvatum | 0–110 | ICBG | 3 | 1.5 | 113 | 0–130 | 0 | 52 | 90 | 100 |
| 3 | 41-A3 | Nonoperative | 8° varus | 0–130 | ICBG | 5 | 0 | 24 | 0–130 | 40 | 70 | 100 | 100 |
| 4 | 41-A2 | IM nail and plate | 15° varus, 10° procurvatum | 0–115 | DBM | 4 | 0 | 37 | 0–130 | 50 | 20 | 100 | 100 |
| 5 | 41-A3 | External fixation | 10° varus, 17° procurvatum | 0–90 | ICBG | 5 | 0 | 25 | 0–130 | 20 | 63 | 100 | 95 |
| 6 | 41-A3 | Enders nails | 7° varus | 0–130 | ICBG | 3 | 1 | 12 | 0–130 | 50 | 15 | 90 | 90 |
| 7 | 41-A3 | External fixation | None | 0–95 | DBM | 4 | 1 | 29 | 0–130 | 20 | 64 | 90 | 100 |
| 8 | 41-A2 | Nonoperative | 20° varus, 5° procurvatum | 0–135 | DBM | 2 | 0 | 17 | 0–135 | 10 | 60 | 100 | 95 |
| 9 | 41-A3 | IM nail | 8° valgus, 11° procurvatum | 10–105 | ICBG | 2 | 0 | 53 | 0–135 | 0 | 31 | 100 | 100 |
| 10 | 41-A2 | IM nail | 4° varus, 7° procurvatum | 0–130 | ICBG | 2 | 0 | 24 | 0–130 | 50 | 100 | 100 | 100 |
| 11 | 41-A2 | IM nail | None | 20–95 | DBM | 3 | 1.5 | 18 | 0–135 | 34 | 15 | 73 | 80 |
| 12 | 41-A3 | IM Nail | 7° varus, 18° procurvatum | 0–130 | DBM | 8 | 0 | 12 | 0–130 | 50 | 60 | 80 | 80 |
| 13 | 41-C2 | LISS plate | 10° recurvatum | 0–135 | ICBG/BMP | 8 | 0 | 20 | 0–135 | 5 | 30 | 60 | 45 |
| 14 | 41-C3 | Bicondylar plating | None | 0–60 | ICBG/BMP | 7 | 0 | 12 | 0–80 | 10 | 45 | 15 | 50 |
| 15 | 41-A3 | IM nail | 3° varus, 13° procurvatum | 0–130 | DBM | 4 | 0 | 10 | 0–130 | 0 | 65 | 100 | 100 |
| 16 | 41-A2 | IM nail | 8° varus, 5° procurvatum | 0–120 | ICBG | 6 | 0 | 24 | 0–130 | 15 | 45 | 100 | 95 |

*MVA* Motor vehicle accident, *LCP* Locked compression plate, *DBM* Demineralized bone matrix, *ICBG* Iliac crest bone graft, *BMP* Bone morphogenetic protein removing a 1–2 cm segment of the fibular shaft. Then, with the nonunion site mobilized and prepared, the tibial fracture was aligned by indirect and direct techniques. A femoral distractor was placed on the concavity of the deformity in the coronal plane, and deformity correction was fine tuned using clamps to appose the fracture to anatomically contoured plates. To correct sagittal plane malalignment, anterior plates or reduction clamps were used depending on the fracture plane obliquity. When satisfactory alignment was obtained, the plate on the lateral tibia was provisionally fixed proximally. In 1 early case, a humeral blade plate was used, and for the remainder a lateral plate (11 locking plates (LCP, Synthes, Paoli, PA) and 4 standard compression plates (LC-DCP, Synthes). After proximal fixation was obtained, an articulated tensioning device was placed distally to achieve compression across the fracture [14, 20, 23]. Regardless of whether a locking plate or a compression plate was used, the fracture site was tensioned and compressed using the standard holes. One or two lag screws were placed across the nonunion site to supplement compression in all but one case (Fig. 1).

Additionally, and especially in patients with purely transverse fractures or with procurvatum deformity, a small fragment reconstruction or compression plate was placed

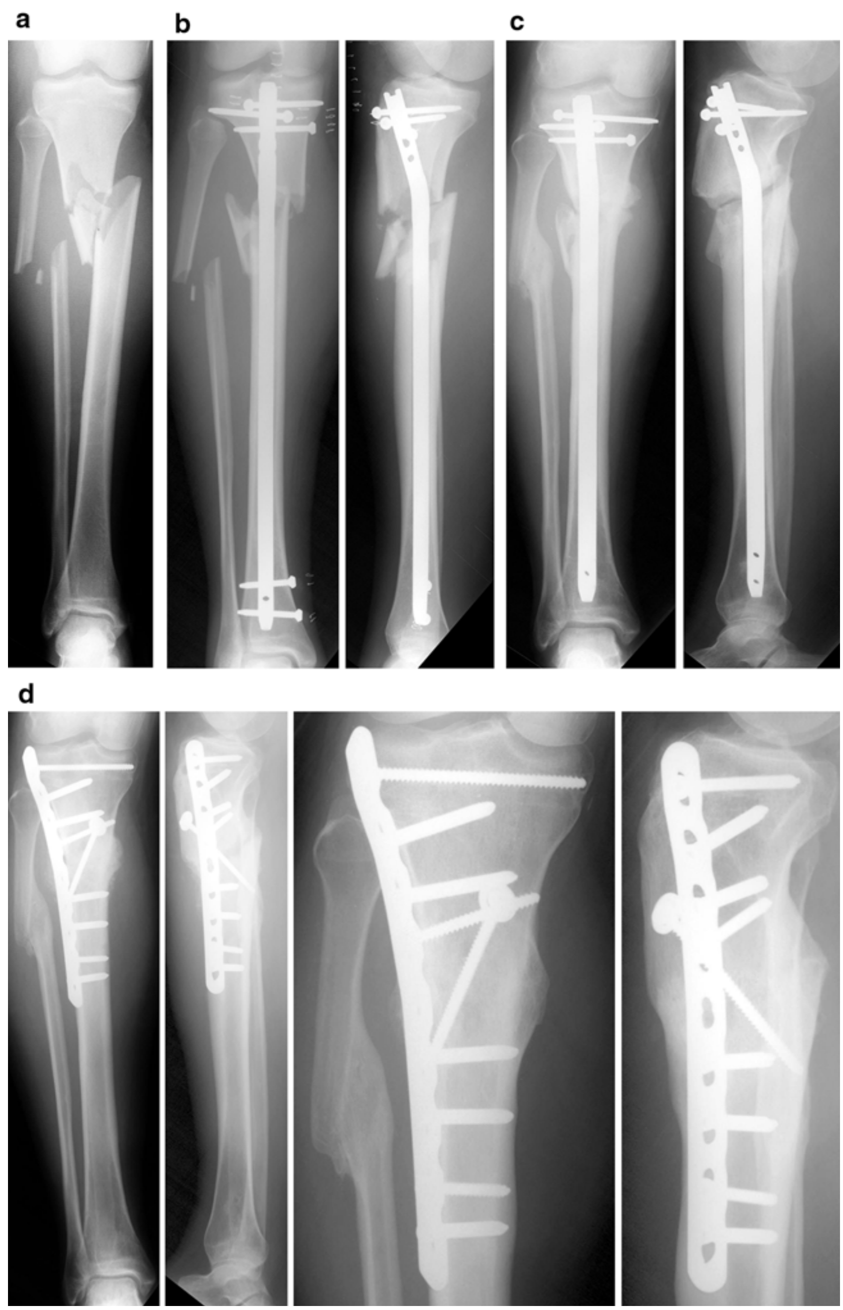


**Fig. 1** Case 10, a 25-year-old male sustained a Type 41-A3 fracture of the right proximal tibia in a motor vehicle accident (**a**). He was treated acutely with an intramedullary nail in 8° of valgus and 11° of procurvatum (**b**). 8 months postoperatively, he was diagnosed with a nonunion (**c**). He was treated surgically with nonunion débridement, indirect deformity correction, compression, autologous bone graft, an anteroposterior lag screw, and a lateral locking plate. Four and a half years later, he had healed in anatomic alignment, had returned to full pain-free activity, and had normal knee range of motion (**d**)

anteriorly just distal to the tibial tubercle to counteract the forces of the extensor mechanism. No intramedullary nails were used for nonunion treatment.

Confirmation of acceptable deformity correction and hardware placement was evaluated directly and using intraoperative fluoroscopic guidance. The knee was moved through its range of motion to test stability and document motion prior to closure. Deep suction drains were placed and a well-padded splint was applied.

On the first postoperative day, the patient was fitted with a hinged knee brace or a walking fracture boot, and continuous passive mobilization (CPM) was initiated. The rehabilitation protocol included gentle active and active-assisted range of motion and touch-down weight bearing under the close supervision of a physical therapist.

## Results

All patients were treated with a similar treatment protocol by one of two fellowship trained orthopaedic traumatologists. Postoperative alignment was within 5° of anatomic in all cases. All nonunions healed at an average of 4.4 months (range 2–8 months) clinically and radiographically. Five patients had a limb length discrepancy, but none were greater than 2 cm. All measurements were performed by a single surgeon not involved in the care of the patients. The average preoperative Knee Society function and knee scores were 25.6 and 50.1, respectively. The average postoperative Knee Society function and knee scores were 87.4 and 89.4, respectively, which was a statistically significant improvement from preoperatively ($P < 0.05$, Table 1). Clinical follow-up averaged 39 months (range 10–113 months).

All patients except for two returned to their subjective pre-injury activity level and were ultimately satisfied with the treatment. One patient, a 59-year-old male, fell from a scaffold and sustained a 41-C2 fracture. He smoked two packs of cigarettes per day, and required two additional revision procedures over an 8 month treatment course, and he continues to have intermittent chronic pain and difficulty ambulating. Another patient, a 46-year-old female who was struck by a car and sustained a 41-C3 fracture, had undergone surgical treatment with bicondylar buttress plating 10 months prior to referral to our institution. During that interval she did not participate in rehabilitation and developed a 20°ankle equinus contracture and knee ROM of 0–60°. Her nonunion healed 7 months following her revision surgery, but she developed severe knee arthrosis and was referred for total knee arthroplasty. One patient fell and refractured her previous nonunion site 7 years postoperatively, and one patient developed an early infection that required irrigation and débridement, but both of these patients had a good functional outcome.

## Discussion

The incidence of nonunion of extraarticular proximal tibial fractures is difficult to assess. Development of a nonunion depends, in part, on the mechanism and energy involved in the injury, and resulting microvascular compromise, soft tissue stripping, comminution, and bone loss. Because fractures of the proximal tibia may occur anywhere along the spectrum of severity, and previous studies have not frequently distinguished between these groups, it is often difficult to compare similar injuries [1, 2, 5]. Regardless, the rate is sufficiently low to preclude analysis of large groups of patients. In this series of 16 patients, the largest, of which we are aware, lateral plating, correction of deformity, and lag screws when possible, led to overall improved function and pain.

The treatment of metaphyseal nonunions can be particularly difficult, and may present unique issues compared to diaphyseal nonunions [23]. The first main variable the surgeon needs to consider is whether the nonunion site is capable of a biologic response. While the biologic capability is usually preserved in metaphyseal bone, severe osteopenia may exist due to prolonged immobilization or limited weight bearing. The soft tissue envelope may be compromised due to traumatic devascularization or chronic infection. Both of these factors may act to devitalize a short periarticular fragment and may make stable internal fixation difficult. Locking periarticular plates for the proximal tibia may be advantageous for achieving implant stability and restoring anatomic alignment. The contour is based on the specific regional anatomy, and can be used as a template to grossly reconstruct the nonunion. Locking screws proximally may allow for improved fixation, allowing for maximal compression across the fracture using the tensioning device. Additionally, using a laterally-based plate in the tension band position is biomechanically sound, [23] and the use of lag screws and the articulated tensioning device may allow the plate to become more of a load-sharing device and improve overall construct stability.

Another specific difficulty in treating these nonunions is the frequently associated deformity. Intramedullary nails have become common for treatment of tibial diaphyseal fractures, and the indications for their use may include proximal fractures as well. Although recent reports have demonstrated that good alignment may be obtained using adjunctive techniques [15, 21, 22] other authors have reported malalignment in 58–84% of cases [8, 16]. Procurvatum deformity is typically seen, usually due to the initial muscle forces on the proximal fragment, and may be exaggerated by poor implant purchase or a nail starting point that is not collinear with the intramedullary canal. These forces must be considered in treating the nonunion, and in fact 9 of the 16 patients we treated (56%) had a component of procurvatum. To address this, we believe it is imperative to perform arthrolysis to minimize continued stress across the nonunion site if the knee is stiff, and possibly augment the fixation with an anterior tension band plate, particularly in transverse fractures where a lag screw is not feasible. In general, nails should be avoided when treating proximal tibial nonunions

Several methods for treating proximal tibial nonunions have been suggested, with varying results. Wu reported on the outcomes of 14 proximal tibial nonunions [26]. All cases had been previously treated unsuccessfully with a lateral plate only, and he recommended revision with medial blade plate fixation. Although generally satisfactory results were reported, this method has several disadvantages, including placing the implant on the compression side of the tibia [11, 23] and the high incidence of soft tissue injury may make the medial region less conducive to surgical dissection. Carpenter and Jupiter [4] used a blade plate laterally in seven proximal tibial nonunions, and reported a union rate of 88%, but only 75% of patients overall regained full ambulation. Lonner et al. [17] reported the results of proximal tibial nonunions treated with a variety of methods, including ORIF, external fixation, cast treatment, and arthroplasty. Although they were able to achieve bone union, there was a high rate of chronic pain, knee stiffness, and functional limitation. McLaren and Blokker [19] used intramedullary nails to treat three nonunions of the proximal tibia, and had residual deformity or chronic knee pain in all patients. The use of Ilizarov techniques has also been described [6].

Limitations of this study included the retrospective nature of the data analysis, which has inherent biases. However, all patients were treated at a single institution by one of two surgeons, and the standardized charting protocols, database entry, and follow-up intervals allowed us to comprehensively analyze complete patient data. Additionally, the utility of the Knee Society outcome score in assessing nonunions around the knee has not been determined, but it is a validated questionnaire, which comprehensively evaluates patients outcomes relative to knee function.

In conclusion, we found overall excellent results in patients with extraarticular proximal tibial nonunions in this series. Using a standardized treatment approach in these difficult cases led to good functional outcomes at an average follow-up of more than 3 years.

## References

1. Anglen JO, Healy WL (1988) Tibial plateau fractures. Orthopedics 11:1527–1534
2. Bhandari M, Audige L, Ellis T, Hanson B (2003) Operative treatment of extra-articular proximal tibial fractures. J Orthop Trauma 17:591–595
3. Borrelli J Jr., Prickett W, Song E, Becker D, Ricci W (2002) Extraosseous blood supply of the tibia and the effects of different plating techniques: a human cadaveric study. J Orthop Trauma 16:691–695
4. Carpenter CA, Jupiter JB (1996) Blade plate reconstruction of metaphyseal nonunion of the tibia. Clin Orthop Relat Res 23–28
5. Ebraheim NA, Sabry FF, Haman SP (2004) Open reduction and internal fixation of 117 tibial plateau fractures. Orthopedics 27:1281–1287
6. Feldman DS, Shin SS, Madan S, Koval KJ (2003) Correction of tibial malunion and nonunion with six-axis analysis deformity correction using the Taylor Spatial Frame. J Orthop Trauma 17:549–554
7. Fracture and dislocation compendium (1996) Orthopaedic Trauma Association Committee for Coding and Classification. J Orthop Trauma 10 Suppl 1:v–ix, 1–154
8. Freedman EL, Johnson EE (1995) Radiographic analysis of tibial fracture malalignment following intramedullary nailing. Clin Orthop Relat Res 315:25–33
9. Gosling T, Schandelmaier P, Muller M, Hankemeier S, Wagner M, Krettek C (2005) Single lateral locked screw plating of bicondylar tibial plateau fractures. Clin Orthop Relat Res 439:207–214
10. Gustilo RB, Anderson JT (1976) Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analyses. J Bone Joint Surg Am 58:453–458
11. Helfet DL, Jupiter JB, Gasser S (1992) Indirect reduction and tension-band plating of tibial non-union with deformity. J Bone Joint Surg Am 74:1286–1297
12. Henley MB, Meier M, Tencer AF (1993) Influences of some design parameters on the biomechanics of the unreamed tibial intramedullary nail. J Orthop Trauma 7:311–319
13. Insall JN, Dorr LD, Scott RD, Scott WN (1989) Rationale of the Knee Society clinical rating system. Clin Orthop Relat Res 248:13–14
14. Johnson KD (1987) Management of malunion and nonunion of the tibia. Orthop Clin North Am 18:157–171
15. Krettek C, Stephan C, Schandelmaier P, Richter M, Pape HC, Miclau T (1999) The use of Poller screws as blocking screws in stabilising tibial fractures treated with small diameter intramedullary nails. J Bone Joint Surg Br 81:963–968
16. Lang GJ, Cohen BE, Bosse MJ, Kellam JF (1995) Proximal third tibial shaft fractures. Should they be nailed? Clin Orthop Relat Res 315:64–74
17. Lonner JH, Siliski JM, Jupiter JB, Lhowe DW (1999) Posttraumatic nonunion of the proximal tibial metaphysis. Am J Orthop 28:523–528
18. Martinez A, Sarmiento A, Latta LL (2003) Closed fractures of the proximal tibia treated with a functional brace. Clin Orthop Relat Res 417:293–302
19. McLaren AC, Blokker CP (1991) Locked intramedullary fixation for metaphyseal malunion and nonunion. Clin Orthop Relat Res 265:253–260
20. Muller ME (1965) Treatment of nonunions by compression. Clin Orthop Relat Res 43:83–92
21. Nork SE, Barei DP, Schildhauer TA, et al (2006) Intramedullary nailing of proximal quarter tibial fractures. J Orthop Trauma 20:523–528
22. Ricci WM, O'Boyle M, Borrelli J, Bellabarba C, Sanders R (2001) Fractures of the proximal third of the tibial shaft treated with intramedullary nails and blocking screws. J Orthop Trauma 15:264–270

23. Rosen H (1979) Compression treatment of long bone pseudarthroses. Clin Orthop Relat Res 138:154–166
24. Stannard JP, Wilson TC, Volgas DA, Alonso JE (2003) Fracture stabilization of proximal tibial fractures with the proximal tibial LISS: early experience in Birmingham, Alabama (USA). Injury 34(Suppl 1):A36–A42
25. Weiner LS, Kelley M, Yang E, et al. (1995) The use of combination internal fixation and hybrid external fixation in severe proximal tibia fractures. J Orthop Trauma 9:244–250
26. Wu CC (2006) Salvage of proximal tibial malunion or nonunion with the use of angled blade plate. Arch Orthop Trauma Surg 126:82–87