# Intramedullary Nailing Combined With Adjunct Plate or Blocking Screw for Proximal Tibial Fractures

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**Technical note**

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**Intramedullary nailing combined with adjunct plate or blocking screw for proximal tibial fractures**

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**Abstract Objective:** To compare the traditional approach of intramedullary nail with an extra plate versus the nail combined with blocking screws for proximal tibia fractures without the knee involved. **Methods:** From January 2013 to January 2017, a total of 36 patients who suffered from proximal tibial fractures unaffecting the knee were enrolled into this prospective study, and divided into two groups by random number table method. Of them, 19 patients received an interlocking intramedullary nail combined with an extra plate for internal fixation of the fractures (the plate group), while the remaining 17 patients had fractures fixed with the nail combined with blocking screws (the screw group). The perioperative, follow-up and radiographic data were compared between the two groups. **Results:** All the 36 patients underwent operation smoothly without iatrogenic neurovascular injuries. The plate group proved superior the screw group regarding to operation time and intraoperative X-ray exposure ($P<0.05$) , nevertheless the former was inferior to the latter in implant cost and hospital stay ($P<0.05$) . The follow-up period lasted for 12～24 months with a mean of

(15.62±4.71) months. There were no statistically significant differences in the time to return ambulation and the time to full weight-bearing activity between the two groups ($P>0.05$) . At the latest follow up, no statistically significant differences were found between the two groups regarding knee range of motion and Johner-Wruhs grades for clinical consequences ($P>0.05$) . In terms of anterior knee pain, the difference between the two groups was not statistically significant ($P>0.05$) . In respect of radiographic assessment, the plate group had significantly less residual malalignment than the screw group, including anteroposterior and lateral displacements, as well as angulations in coronal and sagittal planes ($P<0.05$) . To the latest follow up, all patients in both group got bony healing of the fractures without a statistical difference in fracture healing time between them ($P>0.05$) , and no loosening or breaking of the implants were showed on images in anyone of them. **Conclusion:** Both the nail plus plate and nail plus blocking screw do achieve satisfactory clinical outcomes for proximal tibial fractures unaffecting the knee. By comparison, the nail combined with plate facilitates to regain and maintain better alignment of the leg regardless of higher implant cost.

**Keywords:** proximal tibial fracture, interlocking intramedullary nail, adjunct plate, blocking screw

## 1. Introduction

Proximal tibial fractures account for 5% to 11% of all tibial shaft fractures. This type of fracture is often caused by high-energy injury. In addition to the fracture itself, the fracture is often accompanied by different degrees of soft tissue injury**[1]**. Conservative treatment of fractures at this site often leads to complications, such as fracture malunion, nonunion, rotational displacement, and adjacent joint stiffness**[2]**. In order to avoid these complications, clinicians currently use surgical methods to treat fractures in this area. At present, there are many methods for internal fixation of this type of fracture, such as intramedullary nails, bone plates, and external fixators. However, it is still unclear which type of internal fixation is best[3]. In recent years, with the understanding of clinicians on the importance of skin soft tissue and bone blood transport, it has become more and more common to use the intramedullary nail technique to treat this type of fracture**[4]**. Due to the special anatomy of the proximal tibia, it is easy to use the traditional approach of the intramedullary nail; however, this can cause poor resetting and angular deformity. For this reason, the attachment of a small plate to the nail is advisable. In addition, with the maturity of the barrier nail technology and its application in proximal humerus fractures, new ideas and technology to solve the above problems have been presented that have achieved good clinical results. Consequently, two types of surgical intervention are now available for the treatment of proximal tibial fractures: intramedullary nailing with adjunct plate and intramedullary nailing with blocking screw. However, the evidence is currently insufficient to determine which of these two surgical approaches is better. For this reason, based on the literature that has been published so far and the evidence for the lack of treatment for such fractures, we prospectively analyzed 36 cases of proximal tibial dry fractures admitted to our hospital from January 2013 to January 2017 to compare the efficacy and related factors of each treatment.

## 2. Materials and Methods

### *2.1 Patient selection*

**Inclusion criteria**: 1) Proximal tibial fracture; 2) Can tolerate surgery, and knee joint movement function was normal before this injury; 3) The fracture occurred within 1 week of surgery; 4) Agreed to participate in the study and sign an informed consent form; and 5) Patients with follow-up time ≥ 12 months.

**Exclusion criteria:** 1) Pathological fracture; 2) Severe osteoporosis; 3) Patients with a history of mental illness; 4) Obvious surgical contraindications; 5) Patients with compartment syndrome; 6) Open fractures of Gustilo–Anderson class II and above; 7) Vascular injury patients; 8) Patients with narrow medullary cavity (intramedullary nails cannot be used); 9) Patients with open osteophytes; and 10) Patients with tibial deformity and those whose tibia cannot be fixed with intramedullary nails.

### *2.2 General information*

This study prospectively analyzed 36 cases of proximal tibial dry fractures admitted to the Department of Trauma and Orthopaedics, Xi'an Honghui Hospital from January 2013 to January 2017. Sealed envelopes encoded according to computer randomization order were randomly grouped for the patients under study. The envelopes were opened by a roving nurse after the patient entered the operating room, to inform the surgeon which internal fixation method to adopt. The patients who received the traditional approach of intramedullary nail and small plate internal fixation was classified as the "steel plate" group, and the internal fixation with the barrier nail technique was classified as the "barrier nail" group. The preoperative general information of the two groups of patients is shown in **Table 1**. There was no significant difference in age, gender, injury factors, and fracture types between the two groups ($P>0.05$)。 This study was approved by the ethics committee of this unit, and all patients provided signed, informed consent.

### *2.3 Surgical procedure*

#### *2.3.1 Subgingival approach, intramedullary nail, adjunct plate*

Plate group: Under general anesthesia, the patient is placed in a supine position, and the affected side is raised. Make an incision of about 6 cm in length at the fracture site of the proximal and posterior side of the calf, and make a layer-by-layer incision to expose the fractured end. Be careful not to strip the periosteum in a large area. The anatomical relationship of the fracture reduction can be distinguished. Use after reduction under direct vision After shaping, the 5 to 6-hole 3.5 mm system reconstruction locking bone plate is placed on the posterior medial side of the tibia, and the single cortical locking screws are screwed in in turn. After fluoroscopy confirms the reduction and fixation position is satisfied, close the incision. Then use the anterior inferior patella approach, split the patellar ligament in the middle, clear the subpatellar fat pad, and expose the tibial plateau slope. Before the opening of the medullary cavity, the correct nail entry point should be determined under fluoroscopy. This operation is particularly important. The correct entry point should be located at the anterior midline of the cartilage, slightly higher than the tibial tubercle**[5]**. Use an opener to make a hole in the direction of the guide pin, insert the reamed long guide pin, select the appropriate intramedullary nail and place it along the guide pin after stepwise reaming, and try to make the tip of the tibial intramedullary nail close to the articular surface of the distal tibia. Perform the interlocking nails at the far and near ends. After the far and proximal ends are locked, the tail cap is installed, the saline is flushed, the drainage tube is left, and the incision is sutured layer by layer.

### *2.3.2 Blocking nail technology*

Blocking nail group: The patient is placed in a supine position, and the affected side is raised. Split the patellar ligament in the middle, clear the subpatellar fat pad, and expose the slope of the tibial plateau. Before the opening of the medullary cavity, the correct nail insertion point should be determined under fluoroscopy. Use an opener to make a hole in the direction of the guide pin, insert a finger reducer, and fluoroscopy. Correct the lateral position, remove the finger reducer according to the angled inside and outside of the broken end and the front and back angles, and drill a 2.5 mm Kirschner wire in the proper position as a temporary stop nail, insert the finger reducer again, and see through the broken end. Adjust the position of the blocking nail when the inside and outside of the broken end are angled and the front and back angles. The following steps are the same as the steel plate group.

### *2.4 Postoperative treatment*

All patients were given cephalosporin antibiotics to prevent infection and limb elevation for 24 to 48 hours. X-ray films were reviewed on the second day after surgery, and patients were encouraged to perform primary and passive functional exercises on the knees, ankles, and toes. CPM (Joint function training machine) machines were used to assist exercise if necessary. Anterior and posterior radiographs of the affected tibia were taken after the drainage tube was removed the day following surgery. Wound dressings were removed after two weeks. The patients were followed up once a month for the first three months after the operation, every 3–6 months after 3 months, and every 6–12 months after 1 year. The X-ray film showed that the affected limbs were partially loaded after the formation of the callus, and were completely loaded after the fracture end was healed.

**2.5 Observation index and efficacy evaluation**

The operation time, the number of intraoperative fluoroscopy, the cost of surgical consumables, the length of hospital stay and early complications were recorded in the two groups of patients; the clinical results were evaluated by the time of ground movement, the time of full weight bearing, the range of motion of the knee joint and the Johner-Wruhs rating. Perform imaging examinations and use Freedmanand Johnson's method to measure tibia coronal and sagittal angulation deformities, namely: varus and valgus deformity on the coronal plane and anteroposterior angulation deformity on the sagittal plane, and angulation on any plane >5° is regarded as poor reset **[6]**. Record the fracture healing time. At the last follow-up, the therapeutic effect was evaluated according to the Johner-Wruhs tibial shaft fracture postoperative evaluation standard**[7]**. as follows: Excellent: good fracture healing, no neurological and vascular complications, no internal and external valgus deformity, anterior and posterior angle <5°, rotational shift angle <5°, shortening <5 mm, normal knee and ankle joint activity, subtalar joint activity degree >75%, no pain, normal gait, unlimited exercise; Good: fractures healed well, mild vascular nerve stimulation, internal and external turning angle <5°, anterior and posterior angle <10°, rotational shift angle <10°, shortening <10 mm, knee joint mobility >80%, ankle joint mobility >75%, subtalar joint mobility >50%, occasional pain, normal gait, limited exercise; Fair: fractures healed well, moderate blood vessels, nerve stimulation, internal and external angles <10°, anterior and posterior angles <20°, rotational displacement <20°, shortening <20 mm, knee mobility >75%, ankle joint mobility >50%, subtalar joint mobility <50%, moderate pain, mild lameness, severe exercise is severely restricted; Poor: fracture not healed or bone infection, amputation, severe vascular nerve stimulation, internal and external angulation angle >10°, anterior and posterior angle >20°, rotational displacement >20°, shortening >20 mm, knee joint activity degree <75%, ankle joint activity <50%, severe pain, obvious claudication, cannot do vigorous activity.

**2.6 Statistical analysis**

Statistical analysis was performed using IBM SPSS 19.0 statistical software (SPSS, USA). The homogeneity of variance is expressed by $\bar{x} \pm s$. Two independent sample *t*-tests were used to compare the two groups. The rate was compared using the $\chi^2$ test, and $P < 0.05$ was considered to be statistically significant.

**3 Results**

**3.1. Perioperative condition**

All 36 patients successfully completed the operation without any vascular or nerve injury during the operation. The perioperative data of the two groups of patients are shown in **Table 2.** The operation time and the number of intraoperative fluoroscopy in the plate group were significantly better than those in the blocking nail group ($P<0.05$); but the incision length and intraoperative blood loss in the steel plate group were significantly greater than those in the blocking nail group($P<0.05$); The plate group was significantly lower than the blocking nail group in terms of surgical consumables cost and average hospital stay ($P<0.05$). Of the 19 patients in the steel plate group, 15 wounds healed well as scheduled, 3 wounds healed delayed, 1 wound developed pus, and healed after debridement; 17 wounds in the blocking nail group had 15 wounds healed well as scheduled, and 2 wounds delayed Healed, no pus phenomenon appeared. Of the 19 patients in the steel plate group, there were 5 thrombosis, 1 was proximal thrombosis, and 4 were distal thrombosis; of the 17 patients in the blocking nail group, 3 patients had thrombus, all of which were distal thrombosis.

**3.2 Follow-up results**

Patients in both groups were followed up for 12-24 months after operation, with an average of (15.62±4.71) months. During the follow-up, none of the patients suffered another serious trauma, and there was no revision surgery. The follow-up data of the two groups of patients are shown in **Table 3**. There was no significant difference between the two groups in walking time and full weight bearing time ($P>0.05$). At the last follow-up, there was no significant difference between the two groups in terms of knee range of motion, Johner-Wruhs postoperative functional rating and anterior knee pain ($P>0.05$). At the last follow-up, of the 19 cases in the plate group, 14 cases were completely painless, 4 cases had mild pain while walking, and 1 case had obvious pain; 16 cases walked normally without claudication, 3 cases had mild claudication; 17 cases had normal squatting activities. 2 cases were slightly restricted in squatting activities; 18 cases recovered pre-injury exercise and work ability, and 1 case did not return to the level of pre-injury exercise and work ability. Among the 17 cases in the blocking nail group, 14 cases were completely painless, 2 cases had mild pain while walking, and 1 case had obvious pain; 15 cases walked normally without claudication, 2 cases had mild claudication, 16 cases had normal squatting activities, and 1 case had normal squatting activities. Squatting activities were slightly restricted; 15 cases recovered their pre-injury exercise and work ability, and 2 cases did not return to the level of pre-injury exercise and work ability.A typical case picture is shown in figure (steel plate group 3.3.1, barrier nail group 3.3.2).

**3.3 Image evaluation**

The postoperative residual fracture displacement and imaging bone healing time of the two groups of patients are shown in Table 4. Postoperative images showed that the residual lateral displacement, anteroposterior displacement, coronal and sagittal angulation of the plate group were significantly smaller than those of the blocking nail group, and the differences were statistically significant ($P<0.05$). By the time of the last follow-up, the two groups of patients had achieved imaging bone union. There was no significant difference in fracture healing time between the two groups ($P>0.05$). There was no loosening or displacement of internal fixation in all patients. Images of two typical cases are shown in **Figure 3.1 and 3.2**.

**4. Discussion**

Although intramedullary nailing is standard in the fixation of most femoral and tibial shaft fractures, it is still challenging for proximal tibial fractures**[8]**. Early literature reports that the use of iliac bone marrow nails for the treatment of proximal tibial fractures has a rate of malformation of up to 84%, especially for forward angular and valgus deformities**[9]**. Through the study of the anatomical features of the proximal tibia, this is thought to be due to the knee joint in the high flexion position of the anterior aspect of the tibia and the inner goose foot traction**[10]**.

In order to be able to use intramedullary nails to treat proximal tibial fractures and reduce or avoid the above-mentioned malformation, try to achieve the purpose of anatomical reset. Dunbar**[11]**et al first proposed, before using the intramedullary nail, that 3.5mm system compression plate single-layer cortical fixation should be used for direct reduction of the proximal tibial fracture. After direct reduction, the traditional approach of intramedullary nail should be used to fix the proximal tibial fracture. In the 33 patients he studied, the effect of anatomical reduction after surgery was achieved.In our 19 cases of small inferior nail attachment to the intramedullary nail, we found that the probability of angular displacement and poor force line of the fracture ends was significantly reduced compared to the blocking nail technique. Later retrospective studies showed that the infection rate was not related to the surgical procedure. Yoon et al reached the same conclusion. We also reached this conclusion after comparing the postoperative infection rate between the two groups, that is, there was no difference in the infection rate between the two groups. In the study of Yoon et al, it was first proposed that the inferior approach of intramedullary nail plus small plate surgery can reduce the operation time. The same conclusion was obtained through our research. One of the biggest reasons for this reduction in operating time is that the fracture was opened and fixed under direct vision before fixation with intramedullary nailing. We also consider this factor to result in lower intraoperative fluoroscopy times of this surgical method compared to the blocking nail technique, an important factor for the better overall postoperative reduction. Kubiak et al**[12].** reported that the use of percutaneously assisted intramedullary nailing can solve the above problems, but the precise reduction of the fracture is insufficient. Our pursuit of perfection for resetting is another reason for not adopting this method.

In order to solve the valgus of the anterior aspect of the proximal humerus and the valgus forward angulation caused by the inner goose foot traction in the high flexion position, Krettek et al**[13]**. proposed a blocking nail based on the proximal anatomical features of the humerus. The concept, carried out with biomechanical experiments, proved that the use of barrier nails can significantly reduce the probability of the tibia forward angle. Through the comparative study of its literature, the reduction rate can reach 25%. Since frequent intraoperative fluoroscopy is required in the use of the stab nail technique in order to find an appropriate blocking position, this does not intend to increase the number of surgical fluoroscopy and the amount of radiation, which is also a reason for prolonging the overall operation time. We demonstrate this by statistical analysis of the number of intraoperative radiation and the time of surgery in both groups. However, this procedure has the unparalleled advantages of soft tissue disturbance**[14]**. The soft tissue can be repaired quickly after bony structural force line and parasitic recovery.We compared the average hospitalization days between the two groups, We used a comparative analysis of the average hospitalization days between the two groups, considering that this is also a reason for patients with shorter treatment time in the hospital after using the technique of blocking nails.

We analyzed the statistical analysis of the fracture healing time, nonunion, and knee resection in the treatment of proximal tibial fractures by adding small plate and occlusion nail technique to the submedullary nail. The results were not statistically significant ($P > 0.05$). Although the Steel plate group was open-reset, we fully protected the periosteum during open reduction. In addition, we used the shape-reconstruction to lock the bone plate, which acted as an inner stent to reduce the damage to bone blood. In addition, the auxiliary small plate incision is closed before the insertion of the intramedullary nail, which causes the bone debris and growth factors generated during the reaming to be retained, and the internal factors of bone healing are not destroyed, Therefore, there is no statistically significant difference in the time of fracture healing and nonunion. Therefore, both procedures can be regarded as minimally invasive operations, and the iatrogenic soft tissue injury is small, so there is no significant difference in the statistical analysis of the range of motion at the final review of the knee joint.In the selection of internal fixation consumables, the steel plate group used extra fixed consumables, resulting in a lower average cost of surgical consumables between the two groups. The difference was statistically significant (P <0.05). The most serious complication in this study was anterior knee pain. The incidence of knee pain in the plate group was 26.3%, and this figure was 17.6% in the block group. 31.9% of the report, the author's analysis may be related to the study of patients with open sacral ligament. Djahangiri et al. **[15]** performed an 18-month follow-up of 96 cases of tibial shaft fractures and found that 52% of patients had pain in the patellofemoral ligaments , 14% of patients who do not have sacral ligaments have knee pain. The difference was statistically significant. The incidence of knee pain in the plate group was higher than that in the block group (P <0.05), which may be related to the additional anterior and lateral incisions of the knee joint. It has been reported in the literature in China that the occurrence of anterior knee pain is not related to the sacral ligament, and it is related to the internal fixation in the body for too long. In this study, five cases of anterior knee pain occurred in the plate group, four of which were improved after internal fixation, and three cases of anterior knee pain were occurred in the nail group, and improved after removal of the internal fixation. Toivanen et al. **[16, 17]** reported that the patellofemoral ligament did not reduce the incidence of chronic anterior knee pain; 67% to 71% of the anterior knee pain remained after removal of the intramedullary nail, and the difference after 8 years of follow-up was not statistically significant. However, in this study, there were cases of pain in the sacral ligaments, so the results of the study are biased. Therefore, the causes of knee pain need to be further explored.

## Conclusion

In summary, for proximal tibial fractures, the treatment of fracture healing can be achieved by the intramedullary nail with small plate or block nail technique. Both techniques can achieve satisfactory results in terms of therapeutic effect. However, the former requires additional surgical operation of the incision and internal fixation materials, while the latter requires special surgical operation techniques. Although the former has a lower overall operation time, intraoperative fluoroscopy times, and postoperative horn deformity, the average cost of surgical supplies for this technique is higher and the hospital stay is longer. The latter is exactly the opposite. Both groups patients had complications of anterior knee pain, and this was slightly higher in the plate group. Although this complication was improved after internal fixation and removal, it is worthy of the attention of clinicians.

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## Authors' contributions

Yao Lu designed the study. Jie Li, Qian Wang performed the experimental work. Qian Wang, Zhong Li, and Kun Zhang evaluated the data. Jie Li wrote the manuscript. All authors read and approved the final manuscript

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**Availability of data and materials**

The detailed data and materials of this study were available from the corresponding author through emails on reasonable request.

**Ethics approval and consent to participate**

This study was approved by the Department of Orthopaedic Surgery, Hong Hui Hospital, Xi'an Jiao tong University and followed the Declaration of Helsinki. Informed consent was received from all patients.

**Consent for publication**

Not applicable

**Competing interests**

The authors declare that they have no competing interests.

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# Figures

1 2 3 4 5 6 7 8 9 10 11

### Figure 1

A typical case from the steel plate group A 46-year-old male patient was treated for a left humeral fracture (AO41-A3) following a traffic injury on the fifth day after the injury. The traditional approach was used to fix the intramedullary nail with small plate technique. 1&2:Preoperative and lateral X-ray films showed proximal tibial fracture and displacement was obvious; 3:Immediately after the operation was completed; 4&5:On the second day after surgery, the X-ray films showed that the tibial line was restored and the internal fixation was satisfactory; 6&7: After 3 months, the fracture is almost healed; 8–11:One year after surgery, the fracture was completely healed and appearance and function were restored.


**Figure 2**

A typical case from the blocking nail group A 53-year-old female patient was treated for a proximal fracture of the left tibia (AO41-A2) following a traffic injury. The patient was treated with the nail technique. 1&2: Preoperative and lateral X-ray films showed tibial fracture with obvious displacement; 3: The finger resetter was inserted into the rear side image to show the forward angle; 4: By inserting the blocking nail on the back of the proximal end, the forward angle is eliminated; 5: The front and rear images show that there is still obvious shift inside and outside; 6: Transcutaneous clamp reset is invalid; 7&8: The double plane blocking nail improved the angular displacement and restored the tibial line; 9: Appearance after surgery; 10 & 11: On the second day after surgery, the X-ray films of the anterior and lateral position show that the tibial line was restored and the internal fixation was satisfactory; 12–15: Postoperative fracture healing and functional appearance in June.