



Fixator-assisted nailing of tibial fractures: New surgical technique and presentation of first 30 cases

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ARTICLE INFO

Keywords:

Fixator-assisted nailing
FAN
Tibial fracture
Intramedullary nailing
External fixator
Segmental fracture
Comminuted fracture
Periarticular fracture
Fracture reduction

ABSTRACT

Background: Intramedullary nailing is considered a “gold standard” for treatment of tibial shaft fractures. However, some types of fractures are typically considered as “difficult for nailing”. This group includes the periarticular fractures, fractures of both bones at the same level, comminuted and segmental fractures of the tibia. Fixator-assisted nailing (FAN) is an effective method treatment of these types of fractures. The main requirements for the ideal reduction device are an ease of its installation and an ability of multiplanar fracture reduction. Fixator-assisted nailing (FAN) with the use of two perpendicular to each other monolateral tubular frames perfectly meets these requirements. In this study we present this new surgical technique and the analysis of first 30 cases.

Methods: A prospective analysis was conducted for 30 patients with “difficult for nailing” tibial fractures treated with fixator-assisted nailing in our institution between September 1st, 2017, and March 1st, 2018. The duration of surgery and its different stages, the time of fluoroscopy, difficulties encountered during surgery, were analyzed. Clinical and radiological methods were used to evaluated reduction quality.

Results: In all 30 cases the acceptable reduction was achieved. The mean duration of the surgical procedure was 73.7 ± 3 min. The mean duration of fluoroscopy 85.9 ± 4.8 s. In 7 cases we faced with technical difficulties, which were successfully addressed.

Conclusion: The described technique of FAN is an effective method for the treatment of “difficult for nailing” tibial fractures. Future multi-centered studies with a larger number of patients are needed to validate our results.

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Introduction

Intramedullary nailing is considered a “gold standard” for treatment of tibial shaft fractures [1]. This is due to biomechanical and biological advantages when compared to alternative fixation modalities. The goal of intramedullary nailing for tibia fractures is to achieve and maintain appropriate fracture reduction before and at the time of nail insertion. However, some types of fractures are typically considered as “difficult for nailing”. This group includes periarticular fractures, comminuted and segmental fractures of the tibia, and fractures involving both the tibia and fibula at the same level [2].

Alternative methods have been proposed as a means of improving quality of fracture reduction and its maintenance. These alternative options include open and minimally open reduction, semi-extended nailing, poller screws and wires, the use of a fracture table, skeletal traction, and fixator-assisted nailing (FAN) [3].

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Among all the described methods, FAN most accurately attains desired fracture reduction without additional invasion into the fracture site. Paley D. introduced this term in 1997 for long bones deformities correction. He underlined the advantages of external fixators in restoring the axis of the limb and the advantages of internal fixation for the maintenance of the achieved result [4].

Although FAN is currently a widely used technique for deformity correction, its use remains uncommon in the acute trauma setting [5]. One of the most common methods for FAN is the use of a large femoral distractor. Juttman JW and Kroesen JH in 1991 described the use of AO-distractor in intramedullary nailing of a complex femoral fractures [6]. Two years later Rubinstain RA et al. published the first results of using this technique for tibial fractures [7]. The main advantage of distractor use is its ability to reduce the shortening. However, a monolateral frame only allows for alignment control in a single plane. Therefore, for a flexed knee a manual reduction is necessary in the sagittal plane, which is often challenging in certain types of fractures.

The use of tubular fixators is advantageous due to its simplicity. In the literature various assembly options of such devices are described. In 1994, Moed BR et al. described the use of a monolateral tubular frame as a reduction device [8]. This modification allowed for fracture reduction control in only one plane. Further modifications of this device improved the control of fracture reduction; however, this too was limited by monoplanar alignment control [9–11]. Behera et al. described the use of the tubular external fixator (EX-FIX) as permissive to maintain fracture reduction in multiple planes. They described only one case of FAN with the use of this technique for proximal tibial fracture. This method does not allow performing FAN reduction, however, according to the authors' data, it stably holds the achieved bone alignment when flexing the knee. [12].

There are different circular fixator-based reduction devices described in literature [13–15]. In 2001 Blair et al. proposed a simple half circular reduction device for nailing of tibial fractures. Authors used one K-wire proximally and one distally. As there were just two wires placed in one plane, the device was used primarily as a simple distractor and did not permit reduction control in different planes. Chelnokov et al. described a technique of FAN for proximal tibial fractures using a simple Ilizarov frame. Distinct from Blair's device, this frame utilizes multiple K-wires both proximally and distally, thus allowing a multiplanar control of fracture reduction. The authors reported excellent results in 94.6% of cases. According to authors, the mean duration of surgery was 136 min, which was significantly longer than the performed techniques in their study. Thus, despite the excellent results, the main disadvantage of this technique is its complexity, which leads to an increase time of surgery. Moreover, the design of the study conducted by the authors does not allow one to assess its effectiveness in comparison to other techniques [15,16].

To our knowledge, there is no surgical technique that allows one to perform accurate fracture reduction by means of a tubular external fixation device consisting of two monolateral frames perpendicular to each other, followed by intramedullary nailing in achieved alignment. Thus, the purpose of this manuscript is to introduce a new surgical technique utilizing a fixator-assisted nailing of tibial fractures and the radiologic results of patients who presented with "difficult for nailing" tibia fractures.

Materials and methods

Inclusion criteria

30 continuous patients who presented with "difficult for nailing" tibia fractures at one of two Moscow hospitals (13th

Moscow City Clinical Hospital – Level 2 trauma center; Inozemtcev City Clinical Hospital – Level 1 trauma center) were followed prospectively. All surgeries were performed by four different orthopaedic surgeons. The following fractures were considered as "difficult for nailing": both bones at the same level (AO/OTA 42), fractures of the proximal tibia (AO/OTA 41 A; 42), fractures of the distal tibia (AO/OTA 43 A, 42), comminuted and segmental fractures (AO/OTA 42B, 42C). The study was approved by Hospital Ethical Committee and all patients signed an informed consent prior to the surgery.

Patients characteristics

For the period from September 1, 2017 to March 1, 2018, 30 patients (17 men, 13 women) underwent surgery. The average age was 45.9 ± 4 years (range: 24 to 70 years). The fracture patterns were as follows: Six cases were midshaft tibial fractures of both bones at the same level (42A2 - 2, 42A3 - 4); eight cases were fractures of the proximal tibia (41 A2 - 1; 41 A3 - 2; 42A2 - 1; 42B1 - 2; 42B2 - 1; 42B3 - 1); 11 fractures of the distal tibia (43 A1 - 1; 43 A2 - 1; 43 A3 - 2; 42A1 - 4; 42A2 - 1; 42B1 - 1; 42B3 - 1); and five cases, comminuted and segmental tibial fractures (42B1 - 1; 42C1 - 1; 42C2 - 1; 42C3 - 2). Among them were nine cases of open fractures (Gustilo & Anderson: Type 1–2, Type 2–3, Type 3 A - 1, Type 3B - 3).

Implants

As a reduction device we used standard sets of tubular fixator system with 11 mm radiolucent rods. In two cases we used a large distractor. In most cases we used five mm Schanz screws. In eight cases, proximally, we used short 4 mm Schanz screws to minimize the possibility of a screw-aiming arm conflict. In all cases, we used self-drilling screws. Short Schanz screws were utilized as to not disrupt osteosynthesis

We used UTN/CTN Tibial Nail (DePuy Synthes, Switzerland) in seven cases, in 11 cases - the Expert Tibial Nail (DePuy Synthes, Switzerland), in 6 cases - Trigen Knee Nail (Smith & Nephew, USA) and in 6 cases - Trigen Meta-Nail Tibial Nail (Smith & Nephew, USA). The type of nail used was chosen depending on the length of short fracture fragment with the goal of using at least three locking screws and on surgeon's preference.

Surgical technique

In 17 cases the surgery was performed within the first five days after injury, in nine cases - from days 6 to 10 and in three cases - after day 10. In all cases the patient was placed in a supine position on radiolucent table with the knee flexed at 15° . C-arm was placed on the contralateral side. Fracture tables and skeletal tractions were not used in any of the cases.

Step 1 – Installation of the reduction device

Proximal screw in coronal plane

The site of Schanz screw placement was determined under the control of fluoroscopic control. A 5 mm skin incision and blunt soft tissue dissection should be performed on the medial side. A protective sleeve should be used. The Schanz screw should pass posteriorly to the nail trajectory, from inside to outward parallel to the articular surface of the tibial plateau. The screw should be positioned proximally enough to not conflict with the aiming arm for proximal locking. It is important to consider the close position of the common peroneal nerve in the region near the head of the fibula, therefore, when the Schanz screw is inserted 1–2 cm, it is important to control the further insertion on AP view as not to pass the lateral cortex. (Fig. 1a)

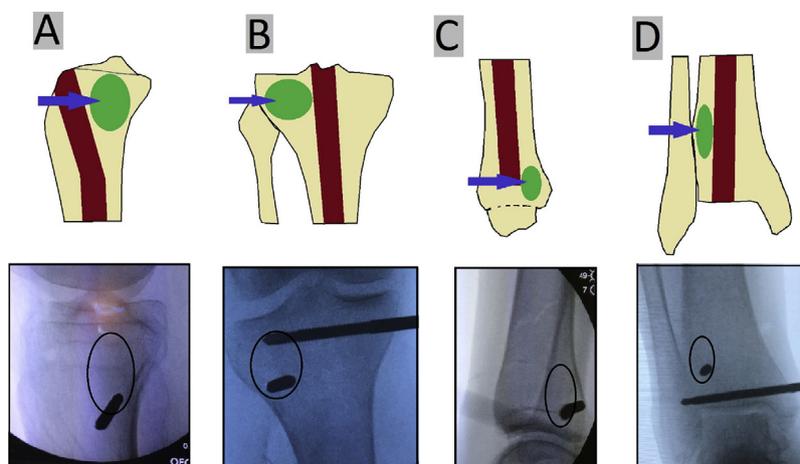


Fig. 1. Schanz screws positions.

Red line – nail pathway. Green spot – preferred screw position. A – proximal coronal screw. B – proximal sagittal screw. C – distal coronal screw. D – distal sagittal screw. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Proximal screw in sagittal plane

The site of Schanz screw placement is determined under fluoroscopic control. A 5 mm skin incision and blunt soft tissue dissection should be performed and a protective sleeve should be used. The Schanz screw should pass lateral to the nail trajectory, from front to back at an angle of 90° to the axis of the tibia. The screw should be positioned proximally enough to not conflict with the aiming arm for proximal locking. It is necessary to consider the close position of the vascular bundle posteriorly, therefore, when the Schanz screw is inserted 1–2 cm, it is important to control the further insertion on lateral view and not to pass the posterior cortex. (Fig. 1b)

Distal screw in coronal plane

The site of Schanz screw placement is determined under fluoroscopic control. A 5 mm skin incision and blunt soft tissue dissection are performed. A protection sleeve should be used. The Schanz screw should pass posteriorly and distally to the nail trajectory, inside to outward, and parallel to the articular surface of ankle joint. When the Schanz screw is inserted 1–2 cm, it is important to control the further insertion on lateral view and not to pass the posterior cortex more than 1–2 mm. (Fig. 1c)

Distal screw in sagittal plane

The site of Schanz screw placement is determined under fluoroscopic control. A 5 mm skin incision and blunt soft tissue dissection should be performed. A protection sleeve should be used. The Schanz screw should pass lateral to the nail trajectory, from front to back at an angle of 90° to the axis of the tibia. The right position of the screw is 3 to 4 cm proximal to the joint line at the upper border of fibular notch. When the Schanz screw is inserted 1–2 cm, it is important to control the further insertion on lateral view and not pass the posterior cortex by more than 1–2 mm. (Fig. 1d).

Step 2 – reduction

The goal of extraarticular fracture treatment is to achieve functional reduction and stable fixation. To achieve a functional reduction, it is necessary to restore limb length, rotational and angular displacement. If two Schanz screws are placed perpendicular to each other and the bone axis, the position of articular plane can be controlled with the high accuracy thus, allowing levelling of the articular surfaces of the tibia parallel to each other.

Shortening and rotational displacement

The first step is the restoration of limb length and rotation. An assistant performs axial traction and eliminates rotational displacement. All clamps are closed and adequate reduction is assessed under fluoroscopy. If the rotational displacement is maintained, 2 distal clamps are relaxed, and the residual displacement is corrected. If length is not restored by manual traction, a large AO distractor can be used instead of the medial frame (Fig. 2).

Angular deformity

The next step is to eliminate the angular displacement in the coronal plane. To do this, the clamps of the medial frame are relaxed and Schanz screws are adjusted parallel to each other. A T-handle can be used as pull/push device for the shorter fragment and while manually manipulating the longer fragment is manipulated manually as to eliminate severe translational displacement. Clamps are closed once the desired reduction is achieved (Fig. 3a).

Sagittal plane displacement is managed using the same principle as in coronal displacement (Fig. 3b). The final fracture reduction is controlled on AP and lateral views. Nailing can be commenced once desired reduction is attained (Fig. 4).

Intramedullary nailing

In 15 cases a standard infra-patellar approach was used with the knee flexed more than 90° , and in 15 cases a suprapatellar



Fig. 2. Traction and reduction of malrotation.

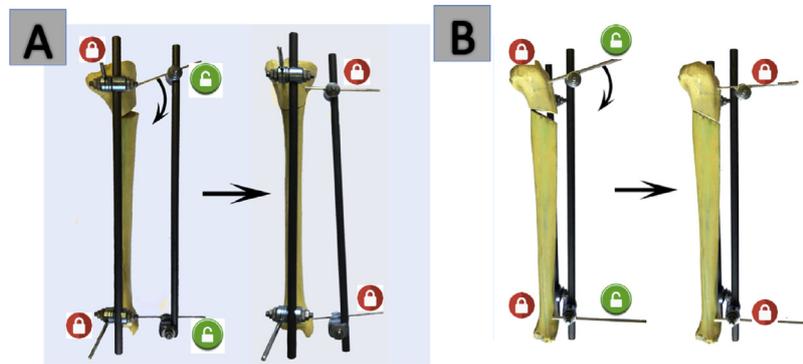


Fig. 3. A – reduction in coronal plane. B – reduction in sagittal plane.



Fig. 4. The reduction achieved with the reduction device. A – sagittal plane; B – coronal plane; C – the photo of the limb after reduction.

approach was used with the knee joint flexed up to 15° . In 11 cases the intramedullary canal was reamed 1 mm over the nail diameter whereas in 19 cases we chose non-reamed nailing. For reduction we used the following techniques: poller wires in 11 cases, Schanz screw as a joystick in two cases, reduction forceps in 2 cases, and an AO distractor in 2 cases (Fig. 5).

Outcome measures

The duration of surgery and its different stages, the time of fluoroscopy, the difficulties we encountered in surgery, their causes and the decisions taken to fix them were noted and analyzed. The duration of surgery was assessed from the moment of first incision, until the last wound was closed. Other events such as ex-fix removal, debridement, skin defect management, VAC-dressing changes and fixation of other fractures was not considered when assessing the duration of the surgery.

We used clinical and radiological methods to evaluate reduction quality. We compared the axis, length, and rotation of the healthy and operated limb. In 4 cases, bilateral fractures of long bones were observed, so comparison with a healthy limb was not possible. On postoperative X-ray films we assessed the axis, length and transverse displacement in AP and lateral views. We also assessed

the coronal and sagittal joint orientation angles according to Paley (aMPTA, aLDTA, aPPTA, aADTA) [17]. We used a CT scan to assess the rotational displacement in cases where it was indicated after clinical examination. Shortening less than 1 cm, angulation in any plane less than 5° , translation less than 0.5 cm, rotational displacement less than 5° were considered as acceptable. All radiological measurements were performed by two independent surgeons.

Results

Intraoperative outcomes

Ex-fix removal was performed in 19 cases prior to surgery. Skin defect reconstruction was performed in 3 cases after nailing. In one case the VAC-dressing was changed. In 6 cases an open reduction and plate fixation of fibula fracture was done. The duration of above-mentioned surgical procedures were excluded from analysis.

The mean duration of surgery was 73.7 ± 3 min (Median = 75 min; Range: 60–100 min). The installation of the reduction device required an average 8.4 ± 0.6 min (Median = 8 min; Range: 6–15 min). It took us an average 7.2 ± 1.2 min (Median = 6.5 min; Range: 4–20 min) to achieve an acceptable reduction. The mean time of fluoroscopy was 85.9 ± 4.8 s (Median = 85 s; Range: 69–131 sec)

Clinical and radiologic results

An angular displacement was observed in 7 cases. A displacement in the coronal plane was observed in 4 patients. In all 4 cases, a residual valgus deformity of one degree was observed. In the sagittal plane, two patients experienced a recurvatum deformity of 4 and one degrees respectively. One patient had a combined angular deformity of 4° of varus and 1° of procurvatum. Any



Fig. 5. Intramedullary nailing. A – guide wire insertion; B – reaming; C – proximal locking; D – distal locking.

angular displacement less than 5° was considered as clinically acceptable.

In 5 cases, a translation of less than 0.5 cm was observed, which we considered as acceptable. Shortening of 0.5 cm was observed in 1 case.

In 3 cases after clinical examination a malrotation was suspected and CT scan was done. Of them in 2 cases we revealed 3 and 4° of external rotation and in 1 case 3° of internal rotation. The revealed rotational displacement was considered as acceptable as it was less than 5°.

In 6 cases, the aMPTA beyond the reference values (85–90 degrees) was observed and in 3 cases of aLDTA beyond the reference values (86–92 degrees), aADTA was beyond the reference values in one case (78–82 degrees), however, only in one case this was a result of malreduction. aPPTA remained within the reference values in all patients (77–84 degrees).

There was one case of deep infection (osteomyelitis) in a patient with an open G&A-3B, AO/OTA-42C3 fracture. This patient also had extensive anterior cortex bone defect. The patient was treated with nail removal, bone resection and transport with the Ilizarov apparatus. There was one case of combination pin-tract and superficial infection of the wound in a patient with open G&A-3B, AO/OTA-42B2 fracture. The patient was successfully treated with local therapy and systemic antibiotics. There were two cases of pin-tract infection, both of which were successful treated with systemic antibiotics.

Technical difficulties cause and solutions

In 23 cases the installation of the reduction device was carried out without any technical difficulties. In 12 cases, the distal Schanz screws interfered with the insertion of at least 1 locking screw. We did not consider this observation as a technical difficulty, since in all cases it was possible to lock the nail distally with at least one screw, and then take off a device without loss of reduction. Moreover, the necessity to keep the frame on before distal locking was only observed in cases with distal tibial fractures. All technical difficulties were successfully addressed. These difficulties, their causes, and measures we took to solve them are described in Table 1.

Discussion

There are some types of tibial fractures, such as periarticular fractures, fracture of both bones at one level, comminuted and

segmental fractures, which are considered as “difficult for nailing”. Problems with manual reduction and its maintenance at the time of nail insertion often result in unacceptable malalignment.

The use of external fixator as a reduction device is an effective method that allows one to accurately control reduction during intramedullary nailing. The main requirements for the ideal reduction device are ease of installation and an ability of multiplanar fracture reduction. Fixator-assisted nailing with the use of two perpendicular monolateral tubular frames may meet these requirements.

Our study demonstrates that the proposed method allowed us to achieve excellent results of intramedullary nailing of tibial fractures. We achieved an acceptable reduction in all 30 cases of “difficult for nailing” fractures. Other reduction techniques should be used in combination with an external fixator if necessary. The technical difficulties experienced in 7 cases were due to surgical mistakes rather than shortcomings of the method.

All Schanz screws should be perpendicular to the bone axis, otherwise problems with fracture reduction could be expected. If shortening is a problem, especially in cases of delayed osteosynthesis, an AO distractor can be used instead of medial frame. The decision to use a distractor is best made prior to surgery. Special attention should be paid to the position of proximal Schanz screw in the sagittal plane. If it is placed too distally and centrally it will interfere with nail insertion and aiming arm connection.

While the distal Schanz screws may interfere with nail locking, it often does not cause technical problems. In cases of proximal and midshaft tibial fractures the reduction device can be taken off after proximal locking. The nail should be locked with at least 1 distal screw before frame take-off in distal fractures.

The described technique is simple and reproducible, what may be concluded from the short duration of fixator installation and fracture reduction.

Conclusion

The proposed technique of fixator-assisted nailing allows to achieve excellent results in patients with “difficult for nailing” tibial fractures. However, the design of this study does not allow to make a conclusion regarding an effectiveness of the method and how it influences on the duration of surgery in comparison to other reduction techniques. Therefore, randomized clinical trials with more patients should be conducted to learn more about the place of this method in nailing of tibial fractures

Table 1
Technical difficulties, causes and solutions in FAN of tibial fractures.

Case #	Age/ Sex	AO/OTA fracture type	Technical difficulty	Cause	Solution
1	48M	42-A3	Reduction in sagittal plane	Proximal Schanz screw in coronal plane was not parallel to the joint line	Manual pressure on apex of the deformity during reaming and nail insertion
2	54M	42-B3	0.5 cm shortening was not resolved by manual traction	Delayed surgery (day 11), AO distractor should be used	Nothing. 0.5 shortening was considered as acceptable
3	37M	42-A1	1 cm shortening was not resolved by manual traction	Delayed surgery (day 12), AO distractor should be used	Conversion of medial frame to AO distractor
4	51F	43-A3	Sagittal Schanz screw conflicted with aiming arm connection	Too distal and central Schanz screw placement	Pointer wire posterior to the nail in distal fragment Anterior frame take-off
5	37M	42-A3	Sagittal Schanz screw conflicted with aiming arm connection	Too distal and central Schanz screw placement	Anterior frame take-off
6	51F	42-C1	Sagittal Schanz screw conflicted with aiming arm connection	Nail insertion was performed with technical error: the aiming arm was connected prior to insertion	After aiming arm was detached, the nail was inserted and locked without any technical difficulties
7	70M	41-A2	Sagittal screw cut-out during reduction	Osteoporosis 4 mm Schanz screws were used proximally	Pointer wire posterior to the nail in proximal fragment Anterior frame take-off

Conflict of interest statement

Dear Editors and reviewers, we report no conflicts of interests for the manuscript titled **“Fixator-assisted nailing of tibial fractures: new surgical technique and presentation of first 30 cases”**. None of the study authors have any financial disclosures nor do any receive royalties from any of the devices discussed in this manuscript.

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