Early complications of preoperative external traction fixation in staged treatment of tibial fractures: a 402 cases series study

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Research article

Keywords: tibial fracture; external fixator; bone traction; complications

DOI: https://doi.org/10.21203/rs.3.rs-41966/v1

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Abstract

**Background and Objective:** Different external skeletal fixators have been widely used in preoperative traction of high-energy tibial fractures prior to a definitive surgical treatment. However, early complications associated with this staged treatment for traction and soft tissue injury recovery have rarely been discussed. This study aimed to analyze the early complications associated with preoperative external traction fixation in the staged treatment of tibial fractures.

**Materials and Methods:** A total of 402 patients with high-energy tibial fractures treated using preoperative external traction fixation at a level-1 trauma center from 2014 to 2018 were enrolled in this retrospective study. Data regarding the demographic information, Tscherne soft tissue injury, fracture site, entry point placement, and duration of traction were recorded. Procedure-related complications such as movement and sensation disorder, vessel injury, discharge, infection, loosening, and iatrogenic fracture were analyzed.

**Results:** The mean patient age was 42.5 (18–71) years and the mean duration of traction was 7.5 (0–26) days. In total, 19 (4.7%) patients presented with procedure-related complications, including technique-associated complications in 6 patients and nursing-associated complications in 13. Differences in the incidence of complications with respect to sex, affected side, soft tissue injury classification, and fracture sites were not observed. However, the number of complications due to hammer insertions was significantly fewer than those due to drill insertions (2.9% vs. 7.4%).

**Conclusion:** The application of preoperative external traction fixation had been proved to be an ideal alternative treatment for high energy tibial fractures. In this study, we found the incidence of early complications of the fixation is low, and it is not significantly associated with the severity of soft tissue injury and fracture site. Although relatively rough and more likely to cause pain, complications of hammer insertions were significantly fewer than drill insertions. The possible reason was higher probability of heat damage and loosening by drilling.

Introduction

High-energy tibial fractures (including AO/OTA-41/42/43/44), also known as “soft tissue injury combined with fracture”, are considered a challenge for orthopedic traumatologists[1]. The soft tissue coverage and vascular distribution of the tibia are limited, leading to a high incidence of complications, such as wound dehiscence and infection[2]. Therefore, the condition of soft tissue often limits the choice for open surgery for high-energy tibial fractures. The selection of a simple and universal preoperative transitional staged therapeutic strategy is particularly important for patients with high-energy tibial fractures who are not suitable for immediate internal fixation surgery.

Various external skeletal fixation procedures and devices have been widely used in preoperative traction of tibial fractures. As with all invasive procedures, the risks and complications associated with inserting pins, such as neurovascular injuries, are occasionally reported in literature [3–6]. However, systematic complication analyses are rarely reported as routine management in staged treatment for preoperative soft tissue amelioration of tibial fractures. In this study, we aimed to investigate the early complications of the application of preoperative external traction fixation in staged treatment of high-energy tibial fractures based on a 402 cases series. The ethics review committee of the institution approved the study protocol.

Materials And Methods

This retrospective study was conducted at a level-I trauma center in a province with a population of more than 60 million in China. Patients who underwent staged treatment of closed tibial fractures and Gustilo I open fractures (AO/OTA-41 proximal tibial fracture, AO/OTA-42 middle tibial fracture, AO/OTA-43 distal tibial fracture or pilon fracture, and AO/OTA-44 ankle fracture) with preoperative external traction fixation between January 2015 to December 2018 were enrolled. The exclusion criteria were, as follows: 1) incomplete medical records; 2) presence of a Gustilo II or III open fracture; 3) previous disability; 4) severe concomitant injury impairing verbal communication; and 5) definitive treatment with external fixator adopted. A total of 402 patients were enrolled.

Demographic information, Tscherne soft tissue classification, fracture site, entry point placement, and duration of traction were recorded. Complications were assessed by physical examinations, as follows: assessment of the range of motion: decreased flexion and extension of the ankle and toes; sensory examination: hypoaesthesia or loss of sensation; vascular examination: decreased or absent pulse in dorsalis pedis or posterior tibial artery; signs of infection: discharge, redness, and swelling of the pin tract; loosening of the pin; and iatrogenic fractures. These physical examinations were performed at three different time-points (before traction, after traction, and after removal). Patients who showed inconsistent results before and after the placement of an external traction fixator were monitored for complications. Two observers collected the aforementioned data the imaging data of the patients from the medical records.
The patient was positioned in the supine position. The limbs on the affected side were propped up using pillows. Based on the fracture site and length of the tibia, the length of the connecting rod was selected preoperatively to avoid a secondary incision. Bone landmarks were marked at both ends of the fracture to indicate the insertion points. After disinfection with 0.5% iodophor and draping, the injured limb was maintained in a neutral position by an assistant. We used 1% lidocaine to infiltrate and locally anesthetize the periosteum at the insertion points on both sides. A scalpel penetrated the skin, and two 4.0-mm smooth Steinmann pins were inserted at the proximal and distal ends of the fracture, parallel to the ground and perpendicular to the bone axis, using a hammer or an electric high-speed power drill. If necessary, the direction was adjusted with an assistant’s guidance before perforation of the first bone cortex. Table 1 shows the specific placement method. Femoral supracondylar and lower tibial pins were selected for tibial plateau fractures, while calcaneal and upper tibial pins were selected for tibial shaft fractures (Fig. 1). Using the length of the healthy limb as a reference, the assistant pulled and tightened the distal pin-to-rod clamp when the length of the limb was restored or exceeded by approximately 1 cm. If necessary, the fracture alignment was reassessed using radiography to determine the need of further adjustments in traction force and transverse connecting rod length for achieving better stability. Correction of fracture shortening and maintenance of soft tissue tension were prioritized; anatomical reduction was not mandatory.

### Table 1

| Position          | Entry point                                                                 | Direction                  |
|-------------------|------------------------------------------------------------------------------|----------------------------|
| Supracondylar Femur | Intersection of horizontal line 2 digits upper patella and sagittal line 3 digits beside the midline | medial to lateral           |
| Proximal Tibia    | 2 cm distal to the point 2 cm beside the highest point of the tibial tubercle | lateral to medial          |
| Distal Tibia      | More than 5 cm above the leading edge of the ankle                            | lateral to medial          |
| Calcaneus         | The posterior 2/3 point of the line between the tip of the medial malleolus and the posterior lower margin of the heel | lateral to medial          |

The operative area was disinfected again immediately after installation of the external traction fixator. Medical alcohol was used to disinfect the pin insertion site and connecting rod twice per day. Patients were discharged home and re-admitted for definitive surgical treatment. Follow-up was conducted through social networking or telephone interviews to assess the soft tissue condition. The standard for re-admittance for definitive treatment depended on the recovery of the injured tissue and was decided by the experienced surgeons.

### Statistical Analysis

SPSS Statistics 20 (IBM Corp, Armonk, New York) was used for statistical analysis. For numerical variables, normality was tested using the Shapiro-Wilk test. As most variables displayed a skewed distribution, the Mann-Whitney U test was used for comparison. The chi-square test or Fisher’s exact test was used for the categorical variables. The tests were 2-sided, and a p-value < 0.05 was considered statistically significant. The incidence rate of complications was further analyzed with respect to the related factors, including sex, affected side, screw placement method, and fracture site.

### Illustrative Cases

**Case 1**

A 55-year-old female patient was injured in a road accident (Fig. 1) and experienced a left tibial plateau fracture (AO/OTA 41-C3) combined with pulmonary injury. The Tscherne soft tissue injury classification was C3, and blisters were observed 12 hours after the injury. The external traction fixator was applied in the ward. The radiographs an increased joint space and partial reduction of the lateral plateau. Blisters subsided on the 10th day after the injury, and a lateral-medial combined incision approach was used for internal fixation.

**Case 2**

A 43-year-old male patient injured his left leg in a fall, resulting in a closed tibial shaft fracture (AO/OTA 42-A1, 4F1A) with skin contusion (Fig. 2). The Tscherne soft tissue injury classification was C2. The external traction fixator was applied after debridement in the emergency room. The radiograph showed satisfactory fracture alignment, and plate fixation was performed 8 days after the injury.

**Case 3**

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A 41-year-old male patient, fell from a height of 3 m, was diagnosed with a right pilon fracture (AO/OTA 43-C3) with a minor traumatic brain injury (Fig. 3). The medial ankle skin showed contusion and stasis. The Tscherne soft tissue injury classification was C2. The external traction fixator was applied after debridement in the emergency room. A radiograph showed satisfactory alignment of the fracture fragments, and plate fixation was performed through anterior external-posterior internal combined incision approach 8 days after the injury.

**Results**

The demographics of the 402 patients are shown in Table 2. The mean age of the patients was 42.5 (18–71) years. Among them, 130 patients sustained injuries in car accidents; 43 patients, on falling from a height; 109 patients, in cycling accidents, 85 patients, during twisting motion, and 35 patients, in other accidents. Seventy-nine patients presented with concurrent comorbidities, as follows: 24 patients with brain trauma; 45 patients with chest injury; and 10 patients with abdominal injury. With the exception of two patients, external traction fixation was discontinued in for all other patients one day before definitive surgery. The average duration of traction was 7.5 (3–26) days.

| Table 2: Demographic data |
|---------------------------|
| **N** | **Complications** | **P** |
| --- | --- | --- |
| **Sex** |  | 0.403 |
| Male | 283 | 15 |
| Female | 119 | 4 |
| **Laterality** |  | 0.833 |
| Left | 160 | 8 |
| Right | 242 | 11 |
| **Pin placement** |  | 0.040* |
| Drill | 163 | 12 |
| Hammer | 239 | 7 |
| **Tscherne classification** |  | 0.722 |
| C1 | 93 | 4 |
| C2 | 213 | 9 |
| C3 | 96 | 6 |
| **Tibial fractures** |  | 0.775 |
| AO41 | 115 | 5 |
| AO42 | 49 | 1 |
| AO43 | 127 | 7 |
| AO44 | 111 | 6 |

A total of 19 patients experienced related complications, including technique-associated complications in 6 patients and nursing-associated complications in 13 patients, leading to a total incidence of 4.7%. The details of complications of the cases are shown in Table 3. Differences were not observed with respect to sex, fracture side, soft tissue injury classification, and complications in different parts of the tibia. Complications associated with hammer insertion were significantly less frequently noted than those associated with drill insertion (2.9 vs. 7.4%). In 6 cases, the complications were technique related, accounting for 31.6% (6/19) of all complications and complete recovery was noted in 83.3% (5/6) of these cases. Case 13 experienced a significant decrease in sensation in the dorsum after drilling into the proximal tibia; hence, it was pulled out immediately. The patient had not completely recovered sensation at the final follow-up. A young male patient (Case 14) experienced a crack fracture around the pin trajectory after hammering into the proximal end of the tibia.
Table 3
Complications details

| Cases | Age | Sex | Injury mechanism | Fractures (AO/OTA) | Pin placement | Complications | Comorbidity | Outcome | Traction duration(days) |
|-------|-----|-----|------------------|-------------------|---------------|---------------|-------------|---------|------------------------|
| 1     | 32  | Male| Traffic trauma   | 43                | Drilling      | Discharge     | -           | Recovered| 9                      |
| 2     | 45  | Male| Fall             | 44                | Hammering     | Cellulitis    | -           | Recovered| 10                     |
| 3     | 56  | Male| Traffic trauma   | 43                | Drilling      | Loosening     | -           | Recovered| 11                     |
| 4     | 41  | Male| Traffic trauma   | 41                | Drilling      | Dorsal foot hypoesthesia | Obesity | Recovered| 10                     |
| 5     | 32  | Female| Traffic trauma | 44                | Hammering     | Effusion      | -           | Recovered| 11                     |
| 6     | 56  | Female| Traffic trauma | 41                | Drilling      | Loosening     | -           | Recovered| 9                      |
| 7     | 67  | Male| Traffic trauma   | 43                | Drilling      | Effusion& Loosening | Osteoporosis | Recovered| 8                      |
| 8     | 55  | Male| Fall             | 41                | Drilling      | Infection & Loosening | Diabetes | Twice debridement | 8          |
| 9     | 67  | Male| Traffic trauma   | 43                | Drilling      | Erysipelas    | Hypertension | Recovered| 6                      |
| 10    | 44  | Male| Traffic trauma   | 41                | Hammering     | Reducing ankle extension | - | Recovered| 4                      |
| 11    | 24  | Male| Traffic trauma   | 41                | Drilling      | Effusion      | -           | Recovered| 6                      |
| 12    | 37  | Male| Traffic trauma   | 44                | Hammering     | Loosening     | -           | Recovered| 6                      |
| 13    | 19  | Male| Traffic trauma   | 44                | Drilling      | Dorsal foot hypoesthesia | - | No | 2                      |
| 14    | 28  | Male| Traffic trauma   | 44                | Hammering     | Iatrogenic fracture | - | Recovered| 8                      |
| 15    | 37  | Female| Traffic trauma | 42                | Drilling     | Reducing hallux extension | Obesity | Recovered| 7                      |
| 16    | 32  | Male| Traffic trauma   | 43                | Drilling      | Effusion      | -           | Recovered| 8                      |
| 17    | 56  | Male| Traffic trauma   | 43                | Hammering     | Reducing hallux extension | • Coronary heart disease | Recovered| 8                      |
| 18    | 45  | Male| Traffic trauma   | 43                | Drilling      | Loosening     | -           | Recovered| 19                     |
| 19    | 56  | Female| Traffic trauma | 44                | Drilling      | Effusion      | Diabetes    | Recovered| 11                     |

Discharge and loosening were the most common complications, accounting for 38.5% (5/13) and 30.8% (4/13) of all complications, respectively. A male patient (Case 7) developed a pin trajectory infection, which spread along the plantar fascia on the 8th day after traction, owing to diabetes mellitus. Plantar necrotizing fasciitis was considered. The patient underwent two procedures of debridement combined with placement of an antibiotic bone cement spacer and vacuum sealing drainage. He was finally cured on the 19th day. Vascular complications and compartment syndrome did not develop in this group.

Discussion
In this study, we aimed to assess analyze the complications associated with preoperative external traction fixation in the staged treatment of tibial fractures and found that the associated complication rate was low and was not significantly associated with the severity of soft tissue injury and fracture site. We did not observe a difference in the incidence of complications with respect to sex, affected side, soft tissue injury classification, and fracture site. However, the incidence of complications associated with hammer insertion was significantly lower than that of those associated with drill insertion.

Tibial plateau, shaft, pilon, and ankle fractures are commonly encountered in trauma centers. Most of these fractures are caused by high-energy injuries, such as falls and traffic accidents, and result in limb shortening or instability, accompanied by severe soft tissue injuries. Soft tissue injury is an important reference when determining the optimal timing of internal fixation surgery, and swelling is a direct indicator. Definitive surgery can be scheduled when soft tissue swelling has reduced as indicated by the appearance of skin wrinkles and epithelialisation of blisters. Therefore, two-staged management, consisting of initial fracture stabilization followed by internal fixation, were performed for these high-energy tibial fractures. In a study on the staged treatment of pilon fractures, Zelle et al. [7] reported that severe soft tissue injuries usually require a transitional stage of 1–4 weeks. Canton et al. [8] reported that internal fixation can be attempted for tibial plateau fractures combined with soft tissue injuries 2–13 days after the injury. Axial traction at the fracture site aids in recovering the limb length and alignment while reducing pain and providing favorable conditions for the elimination of swelling [9]. Accordingly, in our study the mean time to reduce swelling before the surgery was 7.5 days.

The transfixion pin traction system was first used for stabilization before intramedullary nailing of the tibia, a procedure initially described as “traveling traction” [10]. Later, it was improved and simplified by many researchers, and has been widely used as a minimally invasive auxiliary reduction technique in surgery [11–13]. Inspired by the “traveling traction” [14], the insertion point of this technique is the common bone traction point for lower limb fractures, such as that in femoral supracondylar, tibial tubercle, and calcaneal traction. Previous reports have described the selection of the entry points and safety zones in detail [9, 15–17]. We believe that palpation and accurate marking of the insertion points are important steps for reducing the incidence of complications. However, patient anatomy and surgical technique do vary. The irregular triangular structure of the proximal tibia, for example, may result in iatrogenic crack fractures owing to slippage of the traction pin and failure to pass through the two cortices (case 14). In addition, obesity can directly affect the palpation of the bony marks at the point of entry. A Steinmann pin is required to access the bone through the soft tissue, which may cause damage to the nerves, blood vessels, and tendons (Cases 4 and 15).

Linn et al. [3] reported a popliteal artery pseudoaneurysm caused by proximal tibial traction. However, injury to the major vessels can be avoided as long as the insertion site is not located excessively posteriorly to the proximal tibia during the operation [17]. Vascular injury was not noted in our study. Sobol et al. [9] reported that transfixion pin injuries are usually resolved after pin removal. This is in accordance with our study, where 83.3% (5/6) of the patients with transfixion pin injuries recovered completely. We believe that in the future, high-risk patients, such as those with obesity, may warrant B-mode ultrasound-guided pin placement to reduce the development of complications, similar to the method used by Yu et al. [18] for the reduction of femoral neck fractures.

Denham pins are better anchored in the bone but cause more damage to the soft tissue than smooth pins during placement [19]. In our study, soft tissue injury caused by high-speed power drilling was more frequently noted than hammer injury; resolution of the associated complication was difficult. The heat generated during drilling may have caused soft tissue and bone damage [20]. However, pain may be experienced when the of hammer method is used, despite the administration of local anesthesia. In our center, hammers were used for pin insertion during 2015 and 2016; therefore, this approach was abandoned and replaced by drilling. In a recent report, although an association between type of pin site dressing and development of deep infection was not found, nursing care was described as an important factor in pin site infection [21]. In this regard, smooth Steinmann pins are advantageous in that they facilitate discharge. Common pin site infections or erysipelas and swelling can be controlled well with frequent dressing changes and antibiotic treatment. Special caution must be exercised when the procedure is performed for patients with diabetes patients owing to the increased risk of adverse outcomes.

Regardless of the traction type, a certain force must be applied to the soft tissue and ligaments to achieve fracture alignment. Excessive traction can lead to vascular and nerve damage. In this regard, the most serious outcome in tibial fractures is the development of compartment syndrome. Shakespeare [22] reported that every additional 1 kg of traction weight would result in a 5.7% increase in the posterior deep fascial pressure and a 1.6% increase in the anterior fascial pressure. To prevent excessive tension, in our study the length of the healthy limb was used as a reference during traction, and the distal pin was pulled 1 cm beyond the healthy side. This value can be marked on the connecting rod in advance, and can be adjusted depending on the radiographic assessment, if necessary.

Although some researchers found a certain correlation between the Tscheme soft tissue injury classification and postoperative complications [23], our results indicated that the severity of soft tissue injury was not associated with pin insertion complications. It is worth noting that, in all our patients, the pin was placed far from the site of injury. The stabilizing effect of external traction fixation may be more
important than that of conventional bone traction for combined ligament injuries. This is different from bone traction alone, which is contraindicated in ligament injuries.

The limitations of this study include the lack of objective evaluation indicators, such as electromyography to evaluate the sensory and motor parameters. Furthermore, the clinical significance of some complications, such as injury of the medial superior knee artery branch caused by supracondylar traction, was not assessed. In addition, the analysis of the association between temporary fixation and definitive care complications was limited due to lack of a control group. The results of this study must be validated in a prospective comparative study.

Conclusion

Staged treatment of tibial fractures is suitable for soft tissue injury not indicated for immediate internal fixation. External traction fixation for staged treatment is a simple procedure, which involves fewer components, which allows quick installation. In this cases series, we found the incidence of early complications is low and can be safely performed by a junior resident. As a “travelling traction,” it may also play an important role in the prevention of deep venous thrombosis of the lower extremities and chest complications. We believe that external traction fixation is a viable alternative for staged treatment of tibial fractures.

Declarations

Acknowledgements: None

Funding source: None

Conflict of interest statement

There is no conflict of interest issue related to this work.

Ethics approval and consent to participate

This study was approved by the ethics committee of the First Affiliated Hospital of USTC. As for this research, an optout of the informed consent, the information disclosure, and a negative opportunity are guaranteed in the Ethical approval.

Consent for publication

All the patients in this study have given their informed consent for the article to be published.

Availability of data and materials

Please contact author for data requests.

Authors’ contributions

ZWB and YJZ conceived and designed the study. YJZ collected the data and wrote the manuscript. ZWB and DQR read, corrected, and approved the final manuscript. All authors read and approved the final manuscript.

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Figures
Figure 1

Illustration for external traction fixator. A: AO/OTA-41 with the femoral supracondylar and lower tibia entry point; B: AO/OTA-42/43/44 with the upper tibia and calcaneus entry point; C: Traction after fracture, restoring alignment and length through ligament tension.

Figure 2

Illustrative case 1. A: Radiograph after injury (AO/OTA-41-C3); B: Soft tissue swelling and blisters before external traction fixator installing; C: Ten days after external traction fixator application. D: Preoperative radiograph showed increased joint space and improved plateau alignment; E: Postoperative radiograph.
Figure 3

Illustrative case 2. A: Radiograph after injury (42-A1,4F1A); B: Soft tissue swelling and skin contusion before external traction fixator installing; C: external traction fixator application. D: Preoperative radiograph showed a satisfactory fracture alignment.

Figure 4

Illustrative case 3. A: Radiograph after injury (AO/OTA 43-C3); B: Soft tissue swelling and skin contusion after external traction fixator application; C: Preoperative radiograph showed an improved fracture alignment; D: Postoperative radiograph showed a plate combined fixation.