



External Fixation of Proximal Tibia Fractures

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Arthur Schwarz and Marc Hanschen

10.1 Indications

Fractures of the tibia are among the most frequent fractures in humans often caused by high-energy trauma in the context of traffic accidents [1]. The care is made more difficult by the mostly accompanying severe soft tissue damage and the overall constitution of the traumatized patients. In addition, the type of fracture and age of the patient are also important. Higher age and increasing number of fragments degrade the prognosis [2]. Depending on the localization, fractures of the tibia are classified into proximal, diaphysis, and distal tibial fractures.

Proximal tibial fractures are often a major challenge in the care, as there is often an involvement of the joint or metaphyseal area present in a region with a high mechanical load.

The main indications for an external fixation are an open fracture with major soft tissue injuries and a high risk of an infection, polytrauma patients severely injured, and unstable and articular fractures [3].

In general, fractures of the proximal tibia are classified into intraarticular fractures, comminuted fractures, and fractures with a joint luxation. The intraarticular fractures of the proximal end of the tibia or the so-called plateau fractures constitute about 2% of all fractures and about 9.2% of all fractures of the tibia [1].

This type of lesion usually results from axial loading combined with some angular forces like varus and valgus forces leading to strong bruise of the articular surface as well as of the metaphysis. This type of force application is usually seen in high-energy trauma.

It produces not only complex fractures but also major soft tissue injuries (nerves, muscles, blood vessels, skin) that can be open or closed [4–6]. Therefore, it is usually beneficial to perform a sequential treatment with an initial external fixation followed by a definitive fixation. The aim of this strategy with an unstable patient is to stabilize the complex fracture until the general patients' condition and the soft tissue status are improved [3].

The decision whether to operate or not should be based on the fracture morphology, the soft tissue injuries, and also the patients general condition. Regarding the patients general condition, most polytrauma patients are in a critical hemodynamic state with life-threatening multiple lesions of the head, chest, abdomen, or pelvis. Therefore, the early stage of treatment should focus on stabilizing the patient and avoiding further soft tissue injury while waiting to repair the

A. Schwarz (✉)
Department of Trauma Surgery, Klinikum rechts der Isar, Technical University of Munich, München, Germany
e-mail: Arthur.Schwarz@mri.tum.de

M. Hanschen
Department of Trauma Surgery, University Hospital Klinikum rechts der Isar, School of Medicine, Technical University of Munich, Munich, Germany
e-mail: Marc.Hanschen@mri.tum.de

fracture. A surgical treatment with a proximal fracture of the tibia is required when the joint is unstable and the articular surface is fractured accompanied by an axial deformity.

As there are many operative treatment options mentioned in the literature, we want to focus in this chapter on the external fixation and its surgical approach. This kind of operative treatment gives the surgeon the possibility of a local damage control technique especially for fractures with a severe soft tissue injury. In particular use with polytrauma patients, it gives the option of a quick stabilization of a fracture.

The main goal of an external fixation is to provide a temporary immobilization of the fracture especially with open fractures combined with severe soft tissue injuries (severe contamination) seen in high-energy traumas. This external fixation reduces the swelling and soft tissue compromise and even allows the patient to be transported if needed.

In general, the most common techniques of the external fixation are a temporary fixation or the so-called *fixateur externe*, a hybrid external fixation, a ring external fixation, or a fixator with motion capacity [7]. As the fracture morphology varies, the indications for the several external fixators do as well: The classic temporary external fixator is used with open fractures with a severe soft tissue injury. The hybrid and ring fixator can be used with intraarticular plateau fractures or also as a definitive treatment especially with a high deformity of the joint alignment and the option of a secondary correction of an angular deformity. This type of fixator is often used for patients with low compliance. The fixator with motion capacity is often used with fractures accompanied by a severe luxation of the knee joint.

There are two most common classifications of the proximal tibia fracture: The AO classification and the Schatzker classification which subdivides these injuries into six types (I–VI) [8]. As fractures Schatzker type I–III in low-energy traumas can be treated in a conservative way when undisplaced with an immobilization in a leg splint or knee immobilizer or even an early definitive operative fixation, the high-energy fractures Schatzker type IV–VI should be treated with a

subsequent operative treatment as they are associated with high incidence of soft tissue injuries type I or II according to the Tschern and Oestern classification [9–10].

The goal of an operative treatment of proximal tibia fractures is to include restoration of joint congruity, the normal joint alignment, joint stabilization, as well as the prevention of posttraumatic degenerative joint disease with the risk of a posttraumatic osteoarthritis.

10.2 Surgical Approach

10.2.1 Fixateur Externe

The *fixateur externe* is a minimally invasive technique that has been used as an emergency treatment option for fractures almost anywhere in the world due to the general availability, the uncomplicated sterile use, and the low operational costs.

The general principle of a temporary joint-bridging external fixation is a reduction achieved with distraction. Regarding a fracture of the proximal tibia, an external fixator is mounted to the femur and the tibia without touching the fractured zone. The time required and the operative blood loss are minimal [11].

At the beginning of the operation, the assistant performs a reposition of the fracture by means of a longitudinal pull on the leg to correct the rotation. The patella should be oriented to the ventral direction and the foot should have an external rotation of about 15 degrees. The position of the fracture is marked under the X-ray with a pencil on the skin [12].

The next step is the pin insertion. Two pins should be inserted in each of the distal femur and proximal tibia fragment in the anatomical safe zones.

In general, the pins are inserted in the region of the tibia in the anteroposterior plane in the region of the anatomically safe corridors. If a knee joint-locking fixator is necessary, the pins must be inserted in the anterolateral area of the femur. They can be placed within 30 degrees of anterolateral or 30 degrees posterolateral angle. The pins should be applied not closer than 2 cm to the fracture [13].

The first step is the skin cut and then the blunt preparation on the bone with scissors.

It has proved to be helpful while inserting the pins to start the drill bit with the tip just medial to the anterior crest and with the drill bit vertical to the anteromedial surface. As the drill bit starts to penetrate the surface, the drill is moved more anteriorly until the drill bit is in the desired plane in order to avoid slipping into vessels or nerves. Then the two pins are connected in each bone segment with rods of suitable length. The next step is to connect the pins in each bone segment with rods of suitable length. The rods should be then positioned about 3 cm above the skin. Now the jaws are applied. The first two rods are then connected to a third rod. After the reduction of the fracture is carried out, the jaws will be tightened resulting in the correct anatomical position.

Should a transfixation of the knee joint be necessary, the joint should be fixed in about 20 degrees of deflection.

10.2.2 Hybrid Fixator

The hybrid fixator is intended for the fixation of complex, especially peri-articular, fractures [14]. As with any surgical procedure, careful preoperative planning is also important here. The configuration of the fixator is defined by the fracture pattern and the soft tissue injury. The goal is a precise restoration of the articular surface.

The first step involves placing in the anatomical safe zones of at least two wires which form an

X from the axial view. The course of the peroneal nerve must be taken into account. Typical positions for the wires are from the lateral to medial or from anterolateral to posteromedial approximately at the level of the fibula head [14–15]. The next step is to mount the ring (Fig. 10.1).

A ring of suitable size should be selected which ensures a sufficient distance from the soft tissue. The ring is now centered parallel to the surface and over the tibia. The connecting jaws are then attached on both sides to the wire ends and are connected to the ring via the pivotable connecting jaw. If additional wires are required, the connecting jaws can be used as target devices. In an axial view, a connection to the ring should now be provided on both ends of the wire. The wires are then braced by applying a wire tensioner at the wire end. As a rule, the wires are taped with approx. 100–130 kg [16]. When the desired strain is reached, it should be tightened by fixing the nut. This step should be repeated for all wires.

In order to complete the frame construction, the anterior framework must now be inserted.

Pins are inserted into the tibia diaphysis according to the AO technique, and pivoted jaws are mounted on the pins and connected to each other via a rod to a unilateral anterior frame. The rod must protrude proximally in order to be able to connect it to the ring (Figs. 10.2 and 10.3).

For sufficient stability, the tibia pins should be as far apart as possible and the rod as close to the bone as possible. The anterior frame is now connected to the ring via a further connecting jaw.

Fig. 10.1 Mounting of the ring above the tibial head (PD Dr. Marc Hanschen, Klinikum rechts der Isar, Munich)



Fig. 10.2 Insertion of the anterior frame construction (PD Dr. Marc Hanschen, Klinikum rechts der Isar, Munich)



Fig. 10.3 Connecting the anterior frame with the proximal ring (PD Dr. Marc Hanschen, Klinikum rechts der Isar, Munich)



Fig. 10.4 Fracture repositioning with the anterior frame as well as the ring (PD Dr. Marc Hanschen, Klinikum rechts der Isar, Munich)



Now the fracture repositioning takes place by using the ring as well as the anterior frame as handles for the reduction so as to bring the fragments into the desired position (Fig. 10.4).

When the desired reposition is reached, an assistant should tighten the nuts of the connecting jaws.

The hybrid fixator also offers as additional stabilization options a construct as a delta or triangular frame. The advantage of this method is the possibility of an early functional training of the joint [17]. Fractures with a pronounced dis-

stress situation and difficult soft tissue conditions can even be healed within the hybrid fixator.

10.2.3 Motion Fixator

The traumatic dislocation of the knee joint represents a serious injury to the knee often caused by a high-energy trauma. This injury is often associated with extensive ligament, vascular, and also neural damage. The combination of an injury to the posterolateral or posteromedial capsule-band

structures results in complex instabilities. If there is an open fracture with a dislocation of the knee joint and with a great soft tissue injury or an injury to neurovascular structures, the indication for the attachment of a fixator with motion capacity is given. In addition to the soft tissue management and the care of the vessel injury, the stabilization of the joint and its bony reconstruction is the main focus [18]. Complex capsule-band reconstructions are kept to a minimum in an emergency situation. In this situation, the attachment of a fixator with motion capacity allows dynamic stabilization. This allows an early joint movement. After consolidation of the soft parts, the final band reconstruction can also be carried out with the fixator attached [18].

The attachment of the fixator begins with the identification of the idealized center of rotation on the knee joint. It is located anatomically in the transepicondylar axis near the shoulder of the posterior cruciate ligament [19]. A Kirschner wire is inserted into this pivot point under X-ray control. Subsequently, both femoral and tibial pins are inserted after the AO technique. The femoral pins are inserted from lateral under the M. vastus lateralis or in between the M. vastus lateralis and the M. tensor fasciae latae to avoid a damage to the knee extensor. The tibial pins are again inserted as mentioned in the chapter before. Now, the pins are connected to the wire by means of dynamic rod elements. The fine adjustment of axis and rotation of the unstable joint takes place via spherical additional joints between fixator and jaws. The correct position of the center of rotation is shown in the knee joint in the fact that the wire does not bend in flexion and stretching within the limits of 0-0-80 °. After radiological control of the position, the wire can be removed in the center of rotation.

Subsequently, the fixator is fixed in 10-degree deflection and the joint is brought to light tension by means of the connection of dynamic elements to relieve the pressure on the articular cartilage.

The resting position depends on the soft tissue injury above of the luxated joint.

The short-term immobilization of 4–14 days depends on the soft tissue situation of the luxated knee, until the movement of the joint is released

from 0-0-50 ° and later to a maximum of 0-0-80 ° [20]. After consolidation of the soft tissue situation, the definitive band reconstruction can possibly be performed under the protection of the movement fixator or after its removal.

Studies have shown that the use of a fixator with motion capacity against soft tissue orthoses, in particular the protection of the reconstruction of the posterior cross-band, results in a significant improvement in ligament stability [21].

10.2.4 Ring Fixator

In 1951, Professor Gavriil Ilizarov introduced a new external fixation apparatus and a new technique for fracture repositioning, leg extension, and correction of bone deformities in Kurgan, Russia. The technique revolutionized the handling of many previously unsolvable reconstructive problems. The Ilizarov system has undergone numerous innovations over the past 60 years.

One of these innovations is a hexapod ring fixation system. Although the hexapod ring fixation system is a significant improvement over the original Ilizarov system, it preserves the original principles and methodology of Professor Ilizarov. The system consists essentially of round and half-round rings, which are attached to the bone by wires and cortical screws and are connected by six struts [22, 23]. This allows the surgeon a multiplanar adjustment of external fixator elements.

The hexapod system is used for the fixation of open and closed fractures, limb lengthening by distraction, correction of bone deformities, and treatment of nonunions or pseudarthrosis of long bones.

The highlight of the hexapod system is a computer support, which sets new standards for precise preoperative planning. After entering the patient's maladjustments, the program calculates the exact setting of the strut lengths, which are transmitted by the operator to the hexapod. In addition, the software creates a treatment guide, whereby the operator can determine the correction duration according to the indication [22].

Fig. 10.5 Hexapod system using two full size rings (PD Dr. Marc Hanschen, Klinikum rechts der Isar, Munich)



The external fixation consists of two components: the rings and the struts. The rings distinguish between full and 5/8 rings of different sizes. The struts consist of two aluminum telescopic tubes, one outer and one inner, which can be fixed in various lengths by means of a fixing screw and a clamping disk [22]. In general, the surgeon selects two rings, six struts, and six markers for the struts in preoperative planning. The individual struts are marked with numbers since here the fine adjustment takes place in the postoperative course.

In principle, the assembly of the hexapod is carried out in the same manner as the hybrid fixator with a fixation of the rings through wires brought into the tibia. The difference between these two fixation systems is that the hexapod system gives the surgeon the possibility of a distraction on the bone with its displaceable struts. The correction of the deformity is then performed postoperatively by stepwise strut adjustment according to the preoperatively defined protocol (Fig. 10.5).

10.3 Case: External Fixation of Proximal Tibia Fractures

A 58-year-old man (height 170 cm, weight 95 kg) suffered a car accident as a high-energy trauma on the highway as a driver of a truck. In the process, the driver was rescued by the fire depart-

ment after the right lower leg was trapped. Initially the presentation took place in the nearest hospital with primary diagnosis and the placement of a split cast. The primary diagnostics showed a severe fracture of the proximal tibia (AO C3.3). The radiographs showed a massive dislocation of the tibial head (Fig. 10.6).

At the request of the patient, he was moved to our clinic. Here in the emergency room, clinically, a clearly complex soft tissue situation with stress bubbles and a massive contusion of the skin in the entire anterior knee area were shown (Fig. 10.6). There was no neuromuscular deficit.

For this reason, according to damage control surgery, transfixation was carried out by means of a knee joint-locking fixator. In the course of time, the soft tissue situation improved slowly.

Under careful conditioning of the leg and regular wound care, an improved soft tissue situation could ultimately be achieved so that the definitive operation could be carried out by means of a double-plate osteosynthesis in the interval about 3 weeks after primary care (Fig. 10.6).

The surgical wounds were dry and charmless. Motion capacity and sensibility were always intact. In the course the mobilization under physiotherapeutic guidance was begun. Initially a partial weight-bearing on crutches was prescribed for 8 weeks and a stepwise increased flexion by 30 degrees every 2 weeks under regular active and passive movement with a CPM (continuous passive motion). The patient could be discharged



Fig. 10.6 Case report of a proximal tibia fracture showing the complex soft tissue damage and the process of transfixation as well as final operative treatment with a

double-plate osteosynthesis (PD Dr. Marc Hanschen, Klinikum rechts der Isar, Munich)

from the hospital after about 4 weeks stay in good general condition as well as good ROM of the right knee joint of flexion/extension 60/0/0.

In the follow-up examinations performed by us, a regular course was shown. Until the examination 1 year postoperatively, the patient reached a ROM of flexion/extension of 120/0/0 in the right knee joint with charmless skin conditions. Full load and safe walking were possible.

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