Tibial Shaft Fractures – Management and Treatment Options. A Review of the Current Literature

Zlomeniny diafýzy tibie – možnosti ošetření a léčení. Přehled literatury

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SUMMARY

Treatment of tibial shaft fractures is still discussed controversial. In the present study current literature was reviewed with the objective to demonstrate current recommendations concerning tibial shaft fractures.

Tibial shaft fractures are often caused by high-energy trauma with severe concomitant soft-tissue injuries. Solid bone union without hypertrophy, fast mobilization and full range of motion without further soft-tissue damages are the aims of the therapy. Non-displaced tibial shaft fractures in patients with good compliance can be treated conservatively. Deep venous thrombosis, compartment syndrome, soft tissue injury and chronic regional pain syndrome are the major risks of conservative treatment and need to be required.

Operative treatment can be performed with several different implants. Intramedullary nailing with a huge biomechanical stability seems to be the implant of choice. Only rare indications for plate osteosynthesis can be found. The use of external fixation has declined even though external fixation is still the implant of choice in first line treatment of multiple trauma according to the damage control principles.

Open fractures with precarious blood supply and weak soft tissue covering are vulnerable to complications and remain a challenge for every treating surgeon. Reconstruction of axis, length and rotation is essential for a good outcome. The choice of technique depends on fracture localization, type of fracture, history of concomitant disorders and soft tissue damage.

INTRODUCTION

Tibia shaft fractures are the most common long bone fractures (24). They usually occur in young and active patients and are often due to high-energy trauma like motor vehicle accidents, sports or falls from height. Direct trauma like road traffic accidents often cause concomitant severe soft tissue damage with a high incidence of open fractures (17). The lack of soft tissue covering of the tibial shaft and difficult blood supply make these fractures vulnerable to infection and non-union (26). Tibial shaft fractures are severe injuries and may result in permanent disability.

Several treatment options ranging from non-operative to operative treatment including adjunctive strategies are known. Operative treatment is the most established option. Surgeons can choose from a huge variety of implants ranging from external fixation to intramedullary nailing. Despite a large number of studies published on this topic the method of choice is still controversial but there is a tendency towards intramedullary nailing. This study reviews the current literature and presents the current recommendations concerning tibial shaft fractures.

CLASSIFICATION

Tibial shaft fractures are classified according to the AO classification (Fig. 1) of long bones (31) (Type 42) and are divided into simple, wedge and complex fractures (Type 42. A/B/C). Type A fractures are subdivided into spiral, oblique and transverse fractures, type B into spiral wedge, oblique wedge and transversal wedge fractures. Finally Type C fractures are subdivided into spiral, segmental and irregular fractures.

Closed soft tissue injuries can be classified by the classification of Tscherne/Oestern (49) and open fractures by the classification of Gustilo/Anderson (20) as shown in Table 1 or Tscherne/Oestern.

Tab. 1. Gustilo Anderson Classification of open fractures (20)

Gustilo Grade	Definition
I	Open fracture, clean wound, wound <1 cm in length
II	Open fracture, wound >1 cm in length without extensive soft-tissue damage, flaps, avulsions
II	Open fracture with extensive soft-tissue laceration, damage, or loss or an open segmental fracture. This type also includes open fractures caused by farm injuries, fractures requiring vascular repair, or fractures that have been open for 8 h prior to treatment
IIIA	Type III fracture with adequate periosteal coverage of the fracture bone despite the extensive soft-tissue laceration or damage
IIIB	Type III fracture with extensive soft-tissue loss and periosteal stripping and bone damage. Usually associated with massive contamination. Will often need further soft-tissue coverage procedure (i.e. free or ratational flap)
IIIC	Type III fracture associated with an arterial injury requiring repair, irrespective of degree of soft-tissue injury.

DIAGNOSTIC ALGORITHM

Usually patients are able to describe the mechanism of injury and suffer from severe pain. In the clinical examination they often present instability and malposition together with swelling and hematoma. X-rays in two planes are sufficient as the primary diagnostic tool and should include the knee and ankle. Tomography or MRI can be used in proximal and distal fractures to detect articular fractures.

The diagnosis of soft tissue injuries, vessel damage and compartment syndrome is significantly more challenging. It is indispensable to keep compartment syndrome in mind in every tibial shaft fracture and make sure that there is sufficient blood circulation by palpating and duplex sonography. Patient history must also be checked for diabetes, peripheral artery occlusive disease and allergies.

The consideration of compartment syndrome is mandatory and must be reevaluated and documented repeatedly.

THERAPY

The aims of the therapy of tibial shaft fractures are
– reach full weight bearing fast
– reach solid bony union and avoid pseudarthrosis
– regain full range of motion of the knee and ankle joint
– avoiding infections and further soft tissue damage

Open fractures with precarious blood supply and weak soft tissue covering are vulnerable to complications and remain a challenge for every treating surgeon (20). Reconstruction of axis, length and rotation is essential for a good outcome. In particular axial deviation should be avoided to prevent secondary osteoarthritis of the knee and ankle. The choice of technique depends on fracture localization, type of fracture, history of concomitant disorders and soft tissue damage (29).

Conservative treatment

Stable, non displaced fractures of the tibial shaft can be treated conservatively by cast application (42). Conservative treatment in a thigh plaster is performed for approximately 4 weeks. Afterwards a functional brace can be used for 8 to 12 weeks (42).

X-rays should be performed every 2 weeks. Time of treatment depends on the type of fracture and can be estimated as 8–10 weeks for rotating fractures and at least 12 weeks for transverse fractures (29).

Due to a long period of immobilization conservative treatment includes a high risk of deep venous thrombosis, compartment syndrome, soft tissue injury and chronic regional pain syndrome. Treatment of tibial fractures by casting is associated with the lowest incidence of
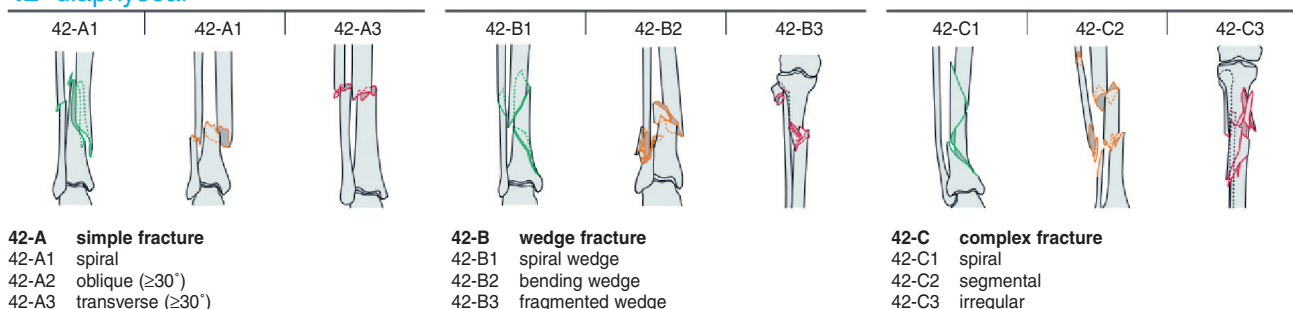

Fig. 1. AO classification of diaphyseal tibial fractures (31).

infection but the highest incidence of delayed union, nonunion and malunion (8). Diagnosis of soft tissue injuries and compartment syndrome is also more difficult in a cast.

According to the AWMF Guidelines conservative treatment is only recommended in non-displaced tibial shaft fractures in patients with good compliance (48).

Operative treatment

Operative treatment with standardized protocols is very common. As mentioned before, long time cast application is highly uncomfortable for the patient. Absolute indications for immediate surgical treatment are for example open fractures, compartment syndrome, concomitant nerv and/or vessel injury or multiple injured patients.

Fig. 2. Closed tibial shaft fracture type 42 B2.3 of a 40-year-old male patient initial and one year after unreamed intramedullary nailing.

Several different implants are available to the orthopedic surgeon. Intramedullary nailing provides a huge biomechanical stability and unreamed intramedullary nails can be used even in higher degrees of soft tissue injury up to grade IIIb [according to Gustilo/Anderson (20)], if wound closure or flap plastic can be performed within 48 hours after stabilization. The use of external fixation has declined, although being a biological osteosynthesis easy to apply.

Only rare indications for plate osteosynthesis due to huge iatrogenic soft tissue damage can be found, even in minimal invasive procedures.

In special indications a two stage stabilization according to the so called "damage control orthopedics" is performed. This can be indicated for example in soft tissue injury of a high degree (open and closed) or in polytraumatized patients (40). The initial stabilization is performed with an external fixator and after recovery of the patient the implant is changed towards an internal osteosynthesis.

Intramedullary nailing

Biomechanical stability and minimally invasive approach with distance to the fracture are the major advantages of intramedullary nailing.

Evidence supports the use of intramedullary nailing in diaphyseal tibial fractures as the implant of choice (3, 4). There is also strong evidence that intramedullary nails offer a benefit over external fixation in open fractures if wound closure is performed soon (4).

Intramedullary nailing is indicated for open and closed isolated tibia shaft fractures (Fig. 2) (AO 42 – Fig. 3) and even extraarticular distal tibial fractures (Fig. 5). This includes oblique, transverse fractures, segmental fractures (Fig. 4), torsion fractures and debris fractures of the tibial shaft as well as open fractures even with bone loss.

Immediately intramedullary nailing is not indicated for severe soft tissue injuries, multiple trauma patients, thoracic trauma, infection, non-union or children with joint growth (41).

Fig. 3. Closed segmental tibial fracture with grade III soft tissue injury with primary external fixation and secondary plate osteosynthesis.

Fig. 4. Closed segmental tibial shaft fracture, Typ 42 C1 with primary external fixation and secondary intramedullary nailing with an adjunctive plate osteosynthesis initially and 6 weeks postoperative of a 30-year-old male patient.

Fig. 5. Distal tibial shaft fracture, Typ 43 A2.2 with primary intramedullary nailing and 6 months postoperative of a 33-year-old male patient.

Intramedullary nailing is well established as a standard treatment for diaphyseal fractures of the long bone despite the negative effects such as endosteal necrosis and systematic fat embolism (25). The resulting biological osteosynthesis conserves the fracture hematoma. Angular stable locking screws facilitate the control of rotation, length and axis and expand the indication for intramedullary nailing (Fig. 2) (26).

There is considerable controversy concerning intramedullary nailing. One key area is whether intramedullary nails should be inserted with reaming or unreamed. Another issue is whether intramedullary nails should be locked with locking screws or not.

Intramedullary reaming deposits the debris formed by reaming at the fracture site, acting like an autologous bone graft and also improves cortical contact with improved stability (38). In vitro studies have shown that intramedullary reaming in combination with an irrigation and aspiration system (Reamer/Irrigator/Aspirator (RIA), Synthes, West Chester, Pennsylvania) and replantation of reaming's into the bone void improve the volume stiffness and strength of callus during the early phase of healing (22).

Unreamed nailing preserves endostal blood supply with quicker healing and lower incidence of infection. Blood supply and soft tissue covering are the major problems in tibial shaft fractures while fat embolism is more relevant in femur fractures. Trauma to endosteal blood supply has shown to be responsible for the negative effects of intramedullary reaming. For this reason unreamed intramedullary nailing has experienced widespread clinical application in open and closed tibial shaft fractures (32). Court-Brown et al. pointed out that reamed nailing is associated with a significantly lower time to union and a reduced requirement for a further operation. They recommended not to use unreamed nailing in the treatment of the common Tscherne C1 tibial fracture with a spiral wedge (9).

Coles et al. presented superior results obtained by reaming with less delayed union, non-union, mal-union and

screw breakage in a review of prospective literature on closed tibial shaft fractures (8). Their findings were supported by Forster et al (13).

Lam et al. also described a beneficial effect of reaming in closed tibial shaft fractures, which was not reflected in open tibial shaft fractures. They concluded that reaming on the one hand disrupts the blood flow to the cortex but on the other hand induces a six fold increase in periosteal blood flow (28, 37). This reaction does not occur in open fractures with frequent severe periosteal damage possibly contributing to the lack of benefit in open fractures.

A recent Cochrane review published by Duan X et al outlined that there is no clear difference in the rate of major re-operations and complications between reamed or unreamed nailing. Low quality evidence could be found that reamed nailing reduces the incidence of major reoperations related to non- union in closed fractures rather than in open fractures (11).

In conclusion reaming acts like an osteogenic debris similar to an autologous bone graft. Improved union rates following reaming have been described in closed tibial shaft fractures while the benefit in open fractures has not yet been proven.

Recently Fuchs et al. published their first short term results using a gentamicin coated intramedullary nail (UTN PROtect®) and demonstrated the possible use in open and closed fractures as the gentamicin coated intramedullary nail was associated with the absence of deep wound infections, good-fracture healing and an increasing weight bearing capacity after six months. Certainly further studies monitoring longer terms of follow up and larger patient cohorts are required (15).

Plate osteosynthesis

Conventional plate osteosynthesis used to be the method of choice for tibial shaft fractures without soft tissue injury until recently being replaced by intramedullary nailing with locking screws (29).

Former developments in plate osteosynthesis led to a surgical technique that attempted to adapt every fragment exactly to anatomy. Such traumatic surgical techniques led to denudation of these fragments, whilst wide exposure of the fracture zone caused delayed healing, nonunion and a tendency towards infection (44). Subsequently the concept of bridging plate and biological osteosynthesis where implemented with the use of angular locking screws (44). These developments allowed careful surgical techniques with the prevention of soft tissue damage. Nevertheless indication for plate osteosynthesis in tibial shaft fractures is rare (29). In current literature indication for plate osteosynthesis can be found in fractures close to metaphysis, intraarticular components, segmental tibial fractures (Figs 3, 4 and 7) or growth joint (41). Plate osteosynthesis is contraindicated in open fractures or patients with former injuries to their lower limb or vessel diseases. If fractures cannot be treated by intramedullary nailing there is evidence that internal plate fixation is superior to external fixation (16).

Fig. 6. Distal tibial shaft frature, Typ 42 C2 with primary external fixation and secondary intramedullary nailing of a 47-year-old man, pre- and postoperative radiographs.

Fig. 7. Typ II open segmental tibial fracture (42 C2) with primary intramedullary nailing and additive plate osteosynthesis of a 52-year-old man two years after an arthrodesis of the ankle joint.

External fixator

Before implementation of intramedullary nailing with locking screws, external fixation was the most common surgical treatment for open fractures of the tibial shaft. A minimally invasive approach and implantation with distance to the fracture side, as well as biological osteosynthesis and improvements in vacuum wound closure and plastic surgery, extended the field to intramedullary nailing. Even type IIIb open fractures can nowadays be treated by primarily intramedullary nailing (29).

External fixation is indicated as primary stabilization for multiple trauma patients, severe soft tissue injury close to the joints or generally inoperable patients. There are no contraindications for external fixation in tibial shaft fractures. For the treatment of multiple trauma patients following the damage control principle, the initial external fixation is the method of choice (46). Further patients at risk are those suffering thoracic trauma, craniocervical injury, hypothermia or coagulopathy. If

procedural change can be performed within 5–10 days there is no increase in the rate of infection (23).

Primary external fixation is also often useful in severe soft tissue injuries without any fractures and provides immobilization.

External fixators are still used for the definitive treatment of juvenile tibia shaft fractures (47).

Soft tissue injuries and open fractures

Infection is the most common and devastating complication of open fractures with a reported incidence of 3-40% (2, 6, 7, 10, 18, 19, 20, 21, 30, 34, 35, 36). The tibia is the most common site of open fractures with an incidence of 49.4% to 63.2% (26). Precarious blood supply and lack of soft tissue coverage explain the high rate of infection and non-union. Rate of infection in grade III-B fracture is up to 50% (20). These complications could be reduced by the development of treatment protocols, which include immediate intravenous antibiotic application, radical soft tissue debridement, early soft tissue covering and stabilization of the fracture (12, 35).

The choice of technique for the stabilization of open tibial fractures still remains controversial. Advantages of external fixation such as ease of application and the limited effect on the blood supply have been outweighed by high rates of pin track infection, difficulties in soft-tissue management and relatively high rates of non-union (50).

Intramedullary nailing has therefore becoming more and more popular even in open fractures. Unreamed intramedullary nailing potentially compromises stability at the fracture site. Reamed intramedullary nailing on the other hand offers improved stability but also suffers a theoretical risk of increasing infection and non-union by destruction of endosteal blood supply. Bhandari et al. undertook a meta-analysis on the treatment of open fractures of the tibial shaft and were able to provide evidence that intramedullary nailing offers a benefit over external fixation. Trends in favor of reamed over unreamed nails were associated with high confidence intervals (4). Several studies support these findings (16, 43). From our point of view, therapeutically strategy has to follow the damage control concept (46). Patients at high risk such as those suffering multiple trauma, thorax or craniocervical injury benefit from a two-stage procedure involving initial external fixation and secondary internal fixation.

There is no increase in infection rate if the definitive stabilization is performed within two weeks. However, open tibial fractures are an emergency and should be treated as soon as possible to avoid infection (26).

Complications

Seroma, necrosis and infection with the late onset of osteomyelitis are the most common complications in closed fractures (8). In some cases they may even require surgical intervention. In general, complications are significantly more frequent in open fractures.

Compartment syndrome complicates tibia fractures with an incidence ranging from 1,4% to 48% in various

studies (33, 52). Especially young patients with diaphyseal fractures are at risk for developing compartment syndrome (33). Patients with diagnosed compartment syndrome require urgent fasciotomy with a secondary complete wound closure according to soft tissue edema. The diagnosis of compartment syndrome is dominated by clinical signs (27) and fasciotomy is indicated when the clinical suspicion of a compartment syndrom exist.

Especially in open fractures, infection is a severe complication requiring radical surgical intervention to avoid chronic osteitis. Once medullary cavity is infected intramedullary nails should be removed and replaced by external fixation. In the case of chronic medullary cavity infection reaming is the method of choice to open sequestered parts. Antibiotic treatment is of major importance but should be accompanied by surgical intervention and radical debridement. Necrotic bone parts must be removed and can be replaced by autologous bone graft or segmental transportation (45).

Precarious blood supply leads to comparatively high rate of delayed- or non-union. Hypertrophic pseudarthrosis needs stability that can be achieved with a method change from intramedullary nailing to plate osteosynthesis or unreamed nailing to reamed intramedullary nailing with a larger implant.

Atrophic nonunion requires vitality that can be achieved with autologous bone graft or implantation of bone morphogenic protein (BMP-7) that has been shown to be a safe and effective option when treating non-unions of the tibia (14). In infectious nonunion successful treatment of infection is the key issue.

Prognosis

Prognosis correlates with injury severity, extent of soft tissue damage and further injuries. The surgical treatment depends on these factors. Unreamed intramedullary nailing is the method of choice with earliest possible weight bearing capacity. Infection rate is estimated with 1-2%. Yet tibia fractures remain vulnerable to complications and often require secondary surgery. According to Bhandari et al. there are three significant indicators of revision surgery: open fracture, transverse fracture pattern and postoperative fracture gap (5). In the presence of all three risk factors reoperation rate is up to 90%

Conclusion

Shaft fractures can be treated with a one or two-stage surgical treatment with intramedullary nailing as the most common therapy (39, 51, 53). In haemodynamically unstable patients early osteosynthesis is of major importance. In multiple trauma patients or those with open fractures or severe soft tissue injuries external fixation can be indicated (1). Bhandari et al. demonstrated that intramedullary nailing reduces the need for revision surgeries, non-union or infection compared to external fixation. There is also a reduced risk of revision surgeries for reamed nails in comparison to unreamed nails (4).

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