

## TIBIAL SHAFT FRACTURES

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**ABSTRACT**

The long-bone fractures occur most frequently in the tibial shaft. Adequate treatment of such fractures avoids consolidation failure, skewed consolidation and reoperation. To classify these fractures, the AO/OTA classification method is still used, but it is worthwhile getting to know the Ellis classification method, which also includes assessment of soft-tissue injuries. There is often an association with compartmental syndrome, and early diagnosis can be achieved through evaluating clinical parameters and constant clinical monitoring. Once the diagnosis has been made, fasciotomy should be performed. It is always difficult to assess consolidation, but the RUST method may help in this. Radiography is assessed in two projections, and points are scored for the presence of the fracture line and a visible bone callus. Today, the dogma of six hours for cleaning

the exposed fracture is under discussion. It is considered that an early start to intravenous antibiotic therapy and the lesion severity are very important. The question of early or late closure of the lesion in an exposed fracture has gone through several phases: sometimes early closure has been indicated and sometimes late closure. Currently, whenever possible, early closure of the lesion is recommended, since this diminishes the risk of infection. Milling of the canal when the intramedullary nail is introduced is still a controversial subject. Despite strong personal positions in favor of milling, studies have shown that there may be some advantage in relation to closed fractures, but not in exposed fractures.

**Keywords** - Tibial Fractures; Fracture Fixation, Intramedullary; Diaphysis

**INTRODUCTION**

The knowledge of the methods of treatment of tibial shaft fractures is important, as this is the most common fracture of the long bones, affecting mainly young men<sup>(1)</sup>; complications such as reoperation, non-consolidation and poor consolidation are also relatively common<sup>(2)</sup>.

The purpose of this paper is to reinforce the basic concepts and describe new practices in the treatment of tibial shaft fracture, seeking to update orthopedists, so that patients with this type of injury can be treated with the most recent practices demonstrated in the literature.

**INJURY CLASSIFICATION**

The most widely used fracture classification is the OTA/AO classification, which takes into consideration the bone region affected, the energy and the mechanism of injury. It classifies simple fractures as A, fragmented wedge fractures as B and multi-fragmented complex fractures as C<sup>(3)</sup>.

This classification system enables good differentiation and understanding of the fracture pattern, leading to a good relationship with the prognosis and clinical outcome<sup>(4)</sup>. It also gives some understanding of the associated soft-tissue injury, but since this is

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not included in the classification, it can lead to the surgeon, if due attention is not paid, to simply classify the fracture without the due correlation with the soft tissue injury.

Although not new, a knowledge of the Ellis classification apud Burwell<sup>(5)</sup> is recommended, because besides the morphology of the fracture, it also evaluates and grades the deviation of the fragments, the conditions of the soft tissues and the energy of the fracture (Table 1).

**Table 1** - The Ellis classification for tibial shaft fracture.

Characteristics	Mild	Moderate	Severe
Deviation	0 to 50% diameter	51 to 100% diameter	100%
Comminution	0 or minimal	0 or 1 fragment	≥ 2 fragments or segments
Soft tissues	Closed grade 0 Open grade I	Closed grade I Open grade II	Closed grades II-III Open grades III-IV
Energy	Low	Moderate	High
Mechanism	Helical	Obliquely oriented/ cross-sectional	Cross-sectional/ fragmented

A thorough analysis of both classifications shows that the OTA/AO classification enables a good description and understanding of the fracture morphology, while the Ellis classification enables a good understanding of soft-tissue injuries. As with all the classifications, none alone can be completely and satisfactorily comprehensive (Figure 1).



**Figure 1** – Left tibial diaphyseal fracture, classified as 42-C2 in the AO/OTA classification, and as severe in the Ellis.

It is recommended that the Ellis classification be used for associated soft-tissue injuries. This can also be complemented by the Tscherne classification for

closed fractures and the Gustilo classification for open fractures, and the OTA/AO classification can be used for planning the treatment.

It is noted that orthopedists should not only evaluate the radiographies to determine the treatment. The condition of the soft tissues is crucial for deciding on the best time to perform definitive surgery and the fixation method, and is closely related to the prognosis.

## COMPARTMENT SYNDROME

Tibial shaft fractures are the most common cause of compartment syndrome<sup>(6)</sup> and, without correct and timely diagnosis that leads to an early treatment, can cause irreparable sequelae.

Clinical suspicion is the key element for early diagnosis of compartment syndrome. In suspected cases, it is essential to monitor the patient continuously, with serial assessment of the affected limb.

Excessive pain that worsens with passive tension of the affected muscle is one of the most sensitive and earliest signs of compartment syndrome<sup>(7)</sup>. Care should be taken with patients with head trauma, spinal cord injury or any other injury leading to peripheral neurological deficit, because these patients may not feel any pain. In these cases, if the disease is suspected, other diagnostic methods should be used.

Palpation of increased pressure and compartment firmness are the only and earliest objective clinical findings. In most cases, peripheral perfusion remains the same, as well as arterial pulses, therefore, they are bad signs for early diagnosis.

Studies show similarity between the various methods for measuring intracompartmental pressure<sup>(8-10)</sup>. According to McQueen et al<sup>(7)</sup>, monitoring of patients who presented a difference in the compartmental pressure and diastolic blood pressure ≤ 30 mmHg showed normal muscle function, even without compartmental release. This data and other preclinical studies indicate that the upper threshold for tissue perfusion pressure is 20 mmHg between compartment pressure and diastolic pressure<sup>(11)</sup>.

Al-Dadah et al<sup>(12)</sup> studied 218 patients with tibial fractures, and failed to demonstrate that the intracompartmental measure of pressure was higher than with continuous monitoring. Of the patients treated for compartment syndrome, 15.6% were in the group

with continuously measured pressure, and 14.7% were in the group with continual assessment. The time to fasciotomy also showed no difference, 22 and 23 hours, respectively.

Blood pressure should be read in all compartments, and is increased 5 cm from the fracture<sup>(11)</sup>.

After the diagnosis, fasciotomy of the four compartments is indicated, preferably by two long incisions – a lateral and a medial incision. The wound should be left open and can be covered with a vacuum dressing application. In case of muscle necrosis, the procedure should be reviewed within 24 to 48 hours. In the case of early diagnosis and absence of muscle necrosis, the patient should be seen again within three to five days, to attempt to close the incisions.

## EVALUATION OF CONSOLIDATION

The consolidation process that occurs after the fixation with intramedullary nail evolves in phases, the first being inflammation, followed by the repair phase and finally remodeling.

The fracture can only be considered healed when the entire consolidation process is completed, i.e., after the remodeling phase is completed, which can take several months.

Many authors consider the fracture consolidation to be complete when the repair phase is completed, at which point full weight-bearing can be allowed on the affected limb. However, due to the lack of full remodeling, the implant could not be removed.

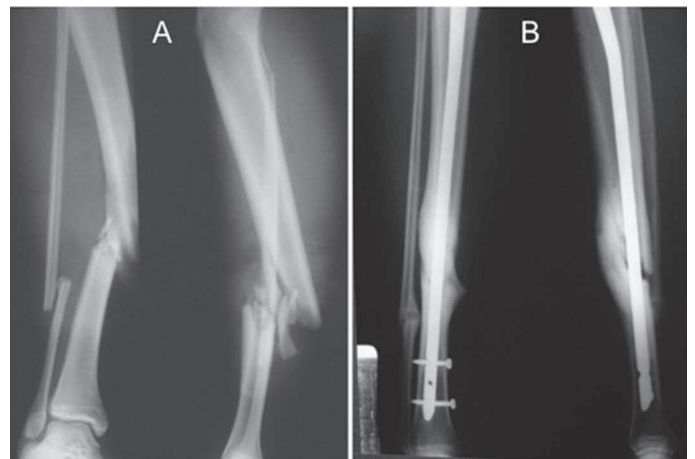
Various definitions have been given of fracture consolidation. One of the most widely accepted is the assessment of the number of cortical bones with bone callus on two orthogonal radiographic views<sup>(13)</sup>. This method is based on an animal study that shows that the number of cortical bones with a bone bridge is a strong predictor of consolidation ( $r = 0.80$ )<sup>(14)</sup>. However, this method has shown a reasonable intra- and interobserver variability<sup>(15)</sup>.

Kooistra et al<sup>(16)</sup> recommend the use of a method called “RUST – Radiographic Union Scale for Tibial Fractures” for evaluating consolidation, since this method has better intra- and interobserver correlation. In this method of assessment, cortical bones are also evaluated in two orthogonal radiographic views, and for each cortical bone, points ranging from one to

three are assigned (Table 2). Thus, a recently operated fracture can be assigned a minimum of four points, and a fully consolidated fracture can be assigned a maximum of 12 points (Figure 2).

**Table 2** - The “RUST – Radiographic Union Scale for Tibial Fractures” method for the assessment of tibial shaft fracture consolidation. The fractures are evaluated in two orthogonal views, with points being assigned for each of the four cortical bones. An unconsolidated fracture can be assigned four points and a fully consolidated fracture can be assigned 12 points

Radiographic analysis		
Points per cortical bone	Bone callus	Fracture line
1	Absent	Visible
2	Present	Visible
3	Present	Invisible



**Figure 2** – A) 42-B3 tibialdiaphysealfacture. B) According to the “RUST” method: posterior cortical one point, anterior cortical three points, medial and lateral cortical two points, total eight points.

## Open fracture – the impact of time on the rate of infection

Lately, much has been discussed on the importance of time-to-treatment and the incidence of infection in open tibial fractures. Some say that time is no longer important, while others still defend the consecrated principle that treatment should be given within six hours.

Defending the principle of treatment within six hours is conceptually a good idea, since it gives the standard that the sooner the treatment is done, the better. However, there is no work in the literature that supports this as the only true principle.

This limit of six hours probably originated with a study by Freidrich, 1898 apud Wangenstein and Wangenstein<sup>(17)</sup> in guinea pigs, which showed that within six hours, massive replication of bacterial colonies occurs, making the surgery procedure less effective.

A clinical trial by Kindsfater et al<sup>(18)</sup> supports the principle of treatment within six hours. The authors, when analyzing the treatment of 47 patients with open tibial fracture, observed a greater incidence of infection in patients treated after more than five hours.

One of the first studies to raise questions about the rule of treatment within six hours was that of Patzakis and Wilkins<sup>(19)</sup>, who found infection rates of 6.8% in injuries treated within 12 hours and 7.1% in those treated after 12 hours, with a difference that was not statistically significant.

Harley et al<sup>(20)</sup> carried out a retrospective review of 215 cases of open fractures to assess the correlation between time-to-treatment and delayed consolidation and infection rate. Although 46% of patients were treated more than eight hours after the accident, it was not possible to establish a correlation between the delayed treatment time and the complications. It was clearly established, however, that their finding on increased infection rate was directly proportional to the severity of the injury.

In another study, Spencer et al<sup>(21)</sup> evaluated 142 open fractures, 60% of which were treated within the first six hours following the accident. The overall rate of infection was 10.4%, and it was not possible to establish any statistical significance between the cases treated within six hours or after this period.

As it can be observed, the studies fail to demonstrate the truth of the six-hour rule; however, all of them show sufficient evidence of the relationship between infection and severity of the injury. Two other facts to be taken into consideration are the conclusion drawn by Patzakis and Wilkins<sup>(19)</sup> who claim that “the most important factor in reducing the infection is early administration of antibiotics” in contrast to Gustilo and Anderson<sup>(22)</sup> who claim that debridement is the most important factor to achieving a good outcome for open fractures. The most appropriate approach would probably be somewhere between these two ideas – antibiotics should be administered as early as possible, and good lavage and debridement should be performed.

In the review by Crowley et al<sup>(23)</sup> on time and infection, the authors concluded that the principle of treatment within six hours must be revised, but debridement should be performed as early as possible.

### **Open tibial fracture – primary or delayed closure?**

Several phases have been assigned to the treatment of fractures after cleaning, with primary or delayed closure. For a long time, delayed closure of the injury was recommended, as in the American experience in the World War II and the Vietnam War, when infection rates for delayed closure injuries were 2.5%<sup>(24)</sup>. The classic study by Gustilo and Anderson<sup>(22)</sup> on early closure of grade I and II injuries showed an infection rate of 6%, but the closure of grade III injuries led to rates of 44%. Therefore, authors recommended that early closure be performed for grade I and II injuries, but for grade III injuries, the wound should be kept open and a surgical revision and delayed closure performed.

Merritt<sup>(25)</sup> found in their study that germs in the cultures before lavage and debridement had no significant correlation with the isolated germs in cases of infection. An important observation was the bacterial growth after debridement, which led authors to suspect that the germs causing the infection were intrahospital germs. The idea of performing early closure of the wound is based on this observation.

The classic studies by Godina<sup>(26)</sup> and Gopal et al<sup>(27)</sup>, who performed early closure of injury or early flap rotation, demonstrate significantly reduced infection rates, even in severe open fractures.

In conclusion, we can use the recommendations by Crowley et al<sup>(23)</sup>, who claim that, to grades I, II and IIIA fractures do not suffer hospital contamination after cleaning and debridement, an early closure of the injury should be performed. The exceptions to this rule are cases of excessive contamination and closure where there is a lot of tension.

For grade IIIB open fractures, if possible, after the debridement, flap rotation should be performed to close the injury. In most services, this is not possible due to the lack of skilled surgeons in the emergency room. The approach then should be to keep the wound open, but protected from secondary contamination, using either a vacuum dressing<sup>(28)</sup> or antibiotic-impregnated cement beads sealed with sterile plastic film.



## To ream or not to ream?

The best way to understand this dilemma is by analyzing the systematic review of Lam et al<sup>(29)</sup> (Table 3).

**Table 3** - Results of the studies analyzed by Lam et al<sup>(29)</sup> in their systematic review of consolidation time and non-consolidation in randomized, prospective clinical trials on the treatment of tibial shaft fractures with reamed and nonreamed intramedullary nail.

Authors	Patients	Non-consolidation		Consolidation	
		Reamed	Nonreamed	Reamed	Nonreamed
Court-Brown et al <sup>(30)</sup>	50	0%	20%	15.4	22.8
Keating et al <sup>(31)</sup>	91	8.5%	12.2%	ns	ns
Blachut et al <sup>(32)</sup>	152	4%	11%		
Finkemeier et al <sup>(33)</sup>	90	23.8%	54.6%		
Ziran et al <sup>(34)</sup>	51	27.3%	13.8%		
Larsen et al <sup>(35)</sup>	48	0%	13%	16.7	25.7
SPRINT closed <sup>(36)</sup>	1319	11%	17%		
SPRINT open <sup>(36)</sup>		29%	24%		

ns = non-significant

## GENERAL CONSIDERATIONS

The result of the analysis of clinical trials shows that in relation to non-consolidation, reaming is

beneficial and has the lowest rate of consolidation failure. It also promotes more rapid consolidation in cases of closed tibial shaft fracture. This difference does not appear to be significant in cases of open fracture.

In the clinical trial with the highest number of patients, SPRINT, there are no separate values only for non-consolidation. The results are presented in compound form i.e. non-consolidation combined with other complications.

Despite these data, the controversy over the benefits of channel reaming remains, because potential biases exist that may lead to misinterpretation and erroneous conclusions.

In the studies analyzed, the definition of non-consolidation and follow-up period was highly varied, and did not allow for a combined statistical evaluation of the available data. Another issue was the small number of cases in some studies. Perhaps the greatest source of bias in most of the studies was non-adherence to the principle of intention-to-treat.

Despite the strong position of some surgeons regarding the mandatory nature of reaming, clinical studies are not sufficiently consistent to support this position without restriction. For closed fractures, reaming appears to offer advantage, but this is not the case for open fractures.

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