Management of Open Fracture

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Abstract

Open fractures are common and their prevalence is increasing in elderly people. The burden of open fractures is high because of economic and social costs. Most open fractures occur in lower limbs. The use of validated protocols, will optimize our outcomes when treating open fractures. The first step began with the proper identification of the fracture characteristics and the hidden soft tissue injury. The use of an adequate and early antibiotic prophylaxis is mandatory and then, we have to perform adequate irrigation and debridement. Finally, we have to decide to temporally fix the fracture or proceed with the definitive fixation method. Recently, the creation of dedicated "orthoplastic" units has increased the outcomes in high-energy tibial fractures. These fractures should be managed in adequate trauma centers that should be used to face all the complications that will appear during the reconstruction procedure because complications can be as high as 50% in high-energy open fractures.

Keywords: open, fracture, antibiotic, reconstruction, management, trauma

1. Introduction

Open fractures are common with an incidence of 30 open fractures for every 100,000 people every year, with an average age of 45 years [1]. Depending on the gender, we can distinguish two peaks: in males between 15 and 19 years and in females in patients older than 90 years [1]. Road traffic accidents are the main mechanisms of injury in these fractures, but we have seen an epidemiologic change in the last years because the incidence of open fractures related to motor vehicle accidents have decreased in the twenty-first century [2]. This lower incidence is due to a high decrease in the number of open fractures in the occupants of motor vehicles probably because of the improvement of vehicles and traffic road security. This situation is in contrast with an increase, in the last years, in the incidence of open fractures in cyclist, motorcyclists and pedestrian accidents [2]. There is also a trend to see an increased incidence of open fractures in the elderly due to all mechanisms (high- and low-energy trauma) [1, 3, 4].

The presence of an open fracture is challenging because of several reasons. First of all, it is a complicated situation because of the generation of a bone defect or the presence of complex fracture patterns; second, we have to solve soft tissue coverage, and in some cases, we also have to recover the blood flow to the extremity.

The management of open fracture has evolved during the last few years, with the introduction of algorithms and the integration of the "orthoplastic" management, in several trauma units in hospitals all over the world [5, 6]. We can see in countries, like United Kingdom, the presence of national protocols to favor an early transfer of patients with these injuries to a trauma center, in order to improve the final outcomes (British Orthopedic Association Standards for Trauma 4 [BOAST 4]: The management of severe lower limb fractures).

In the case of multiple traumatized patients, open fractures should be individually addressed in order to minimize the general complications of a prolonged reconstructive procedure, minimizing the second-hit phenomenon in unstable patients [7–9]. The decision of limb salvage can be difficult to achieve, but in these situations, if we follow a validated protocol, we can optimize the chances of a favorable outcome.

In this chapter, we present the most recent evidence associated with the management of open fractures, with the objective of optimizing the management in these injuries, applying validated protocols in order to maximize the final outcomes obtained in patients with an open fracture.

2. Classification

Several classifications have been used to classify open fractures. We have chosen two from all of them because of the utility and spread through the orthopaedic community. The first one was described by Gustilo [10–12]. He distinguished three scales according to the energy of the mechanism of injury. The full description is reviewed in **Table 1**.

We can see in this classification that grade I injuries are simple fractures, usually with the skin disrupted from the inside because of the spike of the fracture, with limited contamination and good soft tissue coverage. Grade II injuries are usually the effect of a moderate trauma, with more soft tissue contusion and a more complex fracture pattern. Grade III injuries are the consequence of a high-energy trauma; we can find comminution and contamination in the fracture and an extensive soft tissue injury associated with periosteal striping. If the wound can be adequately covered and has no vascular injury, it is sub-classified as A. If the fracture cannot be covered by a soft tissue envelope, and we perform a rotational or free flap procedure to achieve coverage, we are talking about grade B injuries (**Figure 1**). It is important to underline

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	I	II	III-A	III-B	III-C
Energy of mechanism	Low	Moderate	High	High	High
Wound size	<1 cm	>1 cm	Usually >10 cm	Usually >10 cm	Usually >10 cm
Soft tissue injury	Low	Moderate	Extensive	Extensive	Extensive
Contamination	NO	Low	Severe	Variable	Variable
Conminution/ Fracture pattern	No/ Simple	Some/ Simple	Severe/ Complex	Severe/ Complex	Severe/ Complex
Soft tissue coverage	Yes	Yes	Yes	No, requires reconstructive procedure	Variable
Vacular injury injury	No	No	No	No	Yes, require reparation

Table 1. Summary of the Gustilo and Anderson classification, with the division of grade III fractures (red) in grade IIIA, IIIB and IIIC.

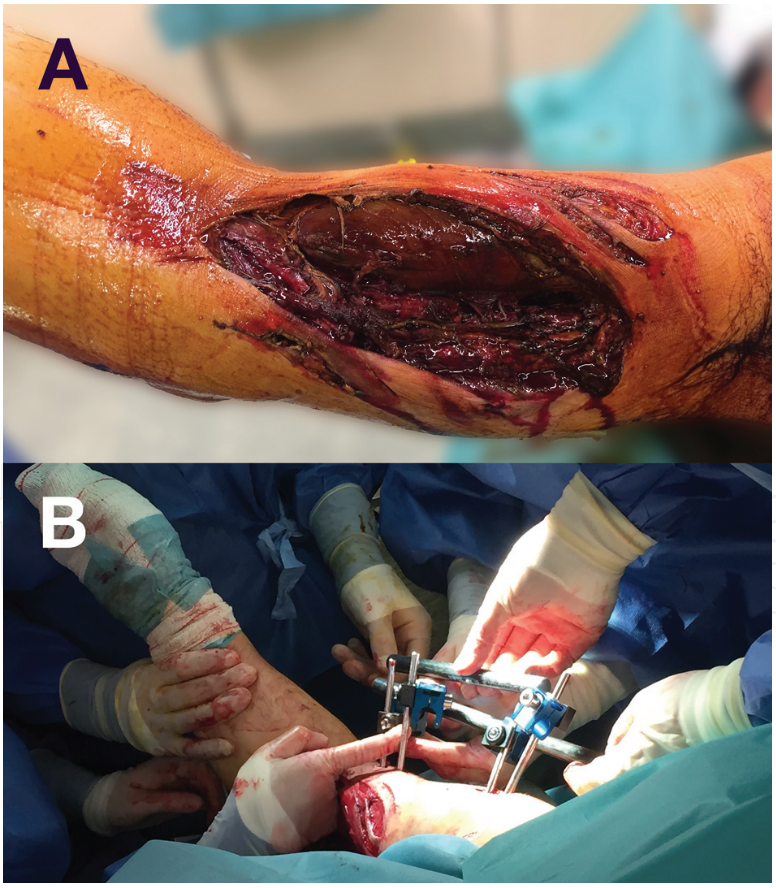

Figure 1. Image A: Clinical picture of an open IIIC fracture of the humerus. Image B: Photograph in the operative theater of the early and initial management, by temporary fixation with an external fixator, to facilitate vascular reconstruction and protection of the repair.

	Skin		Contamination
1	Can be approximated.	1	None or minimal contamination.
2	Cannot be approximated.	2	Surface contamination (easily removed not embedded in bone or deep soft tissues).
3	Extensive degloving.	3a	Imbedded in bone or deep soft tissues.
		3b	High risk environmental conditions (barnyard, fecal, dirty water etc).
	Muscle		**Bone Loss**
1	No muscle in area, no appreciable muscle necrosis, some muscle injury with intact muscle function.	1	None.
2	Loss of muscle but the muscle remains functional, some localized necrosis in the zone of injury that requires excision, intact muscle-tendon unit.	2	Bone missing or devascularized but still some contact between proximal and distal fragments .
3	Dead muscle, loss of muscle function, partial or complete compartment excision, complete disruption of a muscle- tendon unit, muscle defect does not approximate.	3	Segmental bone loss.
	Arterial		
1	No injury.		
2	Arterial injury without ischemia.		
3	Arterial injury with distal ischemia .		

Table 2. Summary of the different conditions included in the classification of the Orthopedic Trauma Association.

that a partial skin or total skin graft is not considered as criteria to classify the fracture as grade IIIB. If we have to face a vascular injury that needs to be repaired, we are talking about grade IIIC. This classification has several utilities: first, it has a prognostic meaning [13], that is, the higher you move in the scale, the chances of infection and complication increase. The second is widespread and used worldwide, and it is clinically useful because it can guide the initial therapy when facing an open fracture.

In 2010, in the Journal of Orthopedic Trauma, an article was published proposing a new classification for open fractures based on a meticulous review of the literature made by the Classification Committee of the Orthopedic Trauma Association (OTA) [14]. This classification is useful to classify open fractures of the upper extremity, lower extremity and pelvis in adults and children in a clinically relevant way. This classification proposed five parameters to be measured: skin, muscle cover, contamination of the wound, arterial injury and bone loss (**Table 2**) [14].

3. Initial management

We have to be aware of several difficulties when initially treating an open fracture, the antibiotic treatment, the time until debridement and the decision of temporally external fixation versus definitive fixation. Most of the evidence of the management of open fractures in long bones is based on open tibial management because it is the most frequent bone involved in open fractures due to its location and characteristics [1].

3.1. Antibiotic prophylaxis

Antibiotic prophylaxis is one of the mainstays of open fracture management. From previous reports, we know that the most common pathogens involved in the colonization of open fractures are Coagulase Negative Staphylococci [15], but depending on the geographic situation, the resistances of these bacteria may change, and orthopedic surgeons should identify the local resistances of the bacteria in their respective area. It is imperative to prescribe antibiotic prophylaxis as soon as possible [16, 17] because early antibiotics diminish infection rates in open fractures [17–19]. This is one of the easiest factors to improve in order to optimize the open fracture management in our clinical practice [20]. The British Orthopedic Association recommends to administering antibiotics within 3 h from the injury. There is also controversy about the perfect antibiotic prophylaxis in the treatment of open fractures. Local or national protocols are of high value if they are adequate to current evidence and population antibiotic resistance. The British Orthopedic Association (BOAST 4) suggests the use of Co-amoxiclav (1.2 g) or Cefuroxime (1.5 g) every 8 h and continue until wound debridement. We should choose clindamycin 600 mg every 6 h if there is a penicillin allergy. Other validated recommendations are the use of cefazolin and gentamicin [21] or piperacillin/tazobactam for 24 h after debridement [22]. Although the use of vancomycin is safe, it is still controversial except for patients allergic to penicillin because it seems that it does not have any benefit in patients with open fractures added to cefazolin [23]. A recent publication suggests a benefit in the use of early vancomycin powder in the wound (locally) to prevent biofilm formation [24]. Other strategies for antibiotic elution in the fracture site are being studied, for example, gentamicin-coated nails are promising, with low infection rates [25], or the use of gentamicin sponges [26].

3.2. Time of debridement

Time of debridement is also a constant controversy [16]. There was a "6-hour rule" in open fracture for early debridement, but recent publications have put this postulate in doubt. There is enough evidence that supports that time for debridement is not a main factor that conditions infection rates or outcomes [16, 27, 28]. This debridement can be safely performed in the first 24 h, and there is consensus to wait within this 24 h for the best conditions, ideally with an orthoplastic team to plan the reconstruction [6, 29]. Primary early closure of open fractures will improve outcomes and diminish septic complication [30].

3.3. Negative pressure wound therapy

The use of negative pressure wound therapy in open fractures that cannot be closed, in the first debridement, is an option that should be considered individually because despite there being evidence that favors its use as a temporary cover until definitive plastic reconstruction [31, 32], there is also a concern about its effect in bacterial growth and local antibiotic effectiveness [33]. Negative wound therapy is an alternative for temporary wound closure in those patients whose condition contraindicates the reconstruction (e.g. polytrauma patients who are not suitable for surgery). In those cases, we should maintain the dressings and change them in short periods of time [32]. A defined limit period of time to use negative pressure wound therapy is not clear, and despite its complications, it is reasonable to extend its use in cases of impossibility of soft tissue coverage because in these situations, it seems to decrease the complications when compared to wet dressings [31]. It is safe to proceed with the conversion from external fixation to internal fixation, in the presence of negative pressure wound therapy, if we hold on the safe interval accepted for conversion from external fixation to internal fixation (less than 2 weeks) [34].

3.4. Initial fixation

Another point of conflict is the initial fixation method for open fractures, particularly, in femur and tibia. It is important to obtain an adequate fixation, in order to minimize pain, optimize wound and facilitate patient manipulation. It seems that grades I and II open fractures can be managed in a similar way like close fractures, with the adequate antibiotic prophylaxis and wound debridement and closure [18], and in the case of tibial fractures, the use of reamed intramedullary nails seems to be reasonable [35] and the use of temporary plating can be a trick to achieve anatomic reduction [36]. More controversies exist in grade III open fracture management. In grade IIIA, the use of non-reamed intramedullary nails seems to be a good and safe option (superior), compared to temporary external fixation in fractures with minimum bone defect, with minimized complications and good union rates [37, 38]. Recent reviews suggest that reamed nailing is not inferior to unreamed nailing in terms of function [38, 39] in grade IIIB open tibial fractures. In these fractures, there is evidence that supports the use of similar treatment options than those used for grade IIIA, and in those situations, early wound coverage is done and minimum bone defect is present [5]. If we are in the presence of a bone defect, the use of a protocoled treatment with temporary external fixation may be useful for definitive treatment. In the case of using an external fixator to temporary or definitive management, we should have in mind that future interventions should avoid damaging essential structures or compromise future reconstructive procedures. New modular devices allow us to achieve adequate fixation with different configurations and prevent inadvertent injuries or compromise future approaches.

Early management of IIIC and some IIIB fractures should be first guided by the need of amputation versus limb salvage, and this topic will be shown in a dedicated chapter. In the case of a IIIC open fracture, vascular repair is mandatory, and our efforts should be focused in obtaining a quick and stable fixation to protect the vascular repair (**Figure 2**). In these cases, we should also consider early preventive fasciotomies to prevent compartment syndrome caused by a revascularized ischemic limb.

3.5. Compartment syndrome

The suspicion of a compartment syndrome should always be present in high-energy trauma, especially in non-conscious patients. Compartment pressure should be measured in case of doubt in these patients, and if there is an increase, or high clinical suspicion, a fasciotomy should be performed [40, 41]. Compartment syndrome is more frequent in young patients with closed fractures, managed by external fixation and intramedullary nailing, but it can also develop in an open fracture, particularly if we closed the fascial compartment with tension [42]. The use of drains and lax closure (or non-closure) of the fascia will help to prevent the increase of the fascial compartment pressure. The use of continuous pressure monitoring

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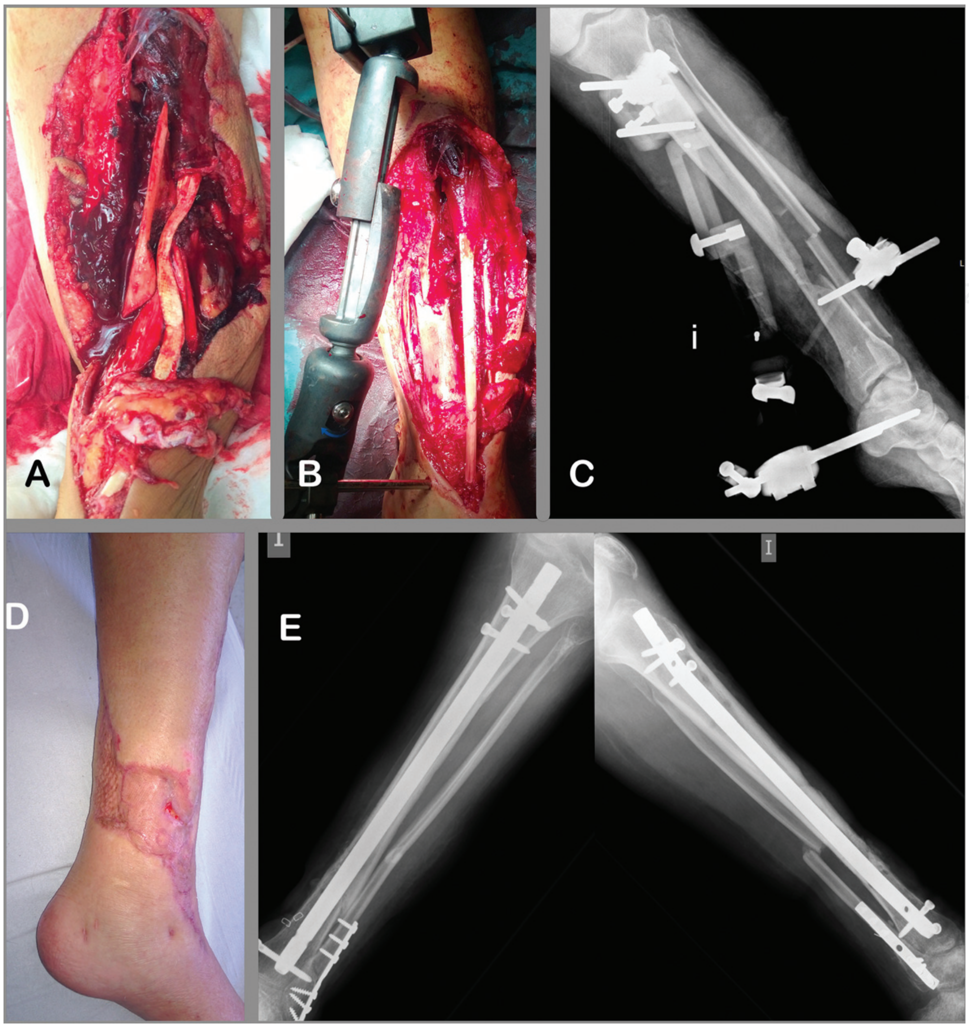

Figure 2. A complete reconstructive procedure in an open fracture grade IIIB tibial fracture, in a 43-year-old female. Image A: photograph in the emergency department of a grade IIIB open fracture in the emergency department. Image B: photograph in the operative theater, temporary fixation of the fracture with an external fixation. Image C: X-ray of the temporarily stabilized fracture with an external fixator, after soft-tissue and bone debridement. Image D: the final soft tissue coverage of the injury. Image E: an anteroposterior and lateral X-ray, after definitive fixation of the fracture with a nail.

seems to be an option for selected patients, but it is not efficient to use routinely in all patients [43, 44].

3.6. Referral to a trauma center

If we have to treat a complex open fracture, in a center without the resources to make the reconstruction, it would be a good option to complete antibiotic prophylaxis, immobilize the injury in a proper way after an initial clinical assessment and refer the patient to a trauma center as soon as possible, especially in the presence of a vascular injury that we would not be able to repair. In the case that the patient needs a long transfer to the definitive centre, or the initial debridement surgery would not be performed within 24 h, it is considered a good option to temporary apply an external fixation, perform the irrigation and debridement and then transfer the patient to a trauma centre to perform the reconstructive procedure.

4. Definitive management

There are several options to finally address an open fracture, and we should select the method appropriate for the clinical situation. In the case of polytrauma patients and high-energy trauma, most of the patients are treated with temporally external fixation and later with definitive conversion to internal fixation (**Figure 2**).

Depending on the situation, we should choose the appropriate moment to perform this conversion to internal fixation. In the case of unstable patients, the best moment for internal conversion is given by patient situation and systemic status, but it is safe to perform this conversion in an interval of time lesser than 14 days [45]. There are several articles that calculate the infection rate of the conversion from external to internal fixation, with percentages that move between 0 and 40, depending on the interval between the injury and the definitive internal fixation with a nail, in long bones of the lower limb (**Table 3**).

In the case of upper extremity, the use of plates is more common, and in humeral open fractures, it is safe to perform the conversion from external fixation to a plate during the first 2 weeks after the injury, with a reasonable complication rate [56].

In some circumstances, we may have to treat a fracture fixed with an external fixator for a long time (more than 4 weeks). In this situation, it is reasonable to retire the external fixator, use an orthosis or a cast, and wait for 2–4 weeks to perform the definitive internal fixation, if there are no septic complications. Another option is to use an external fixator as the definitive device to treat the fracture; this is a good option in patients who are not amenable for internal fixation.

Author	Year	N	Open fractures (%)	Days	Infection (%)
Gill	2016	84	100	12 (7-14)	7
Galvin	2015	125	0	7	2,5
Moody	2009	58	88	9	26
Harwood	2006	98	29	14	5,4
Nowotarski	2000	59	32	7	1,7
Scalea	2000	35	Unknown	7	2,3
Paderni	2001	5	83	50	40
Winkler	1998	43	30	12	2,3
Hontzsch	1993	62	74	15	0
Marshall	1991	4	33	Unknown	0
Wu	1991	15	100	5	13

Table 3. A review of articles is given, which focuses on the complication rate, after conversion from external fixation to internal fixation [34, 46–55].

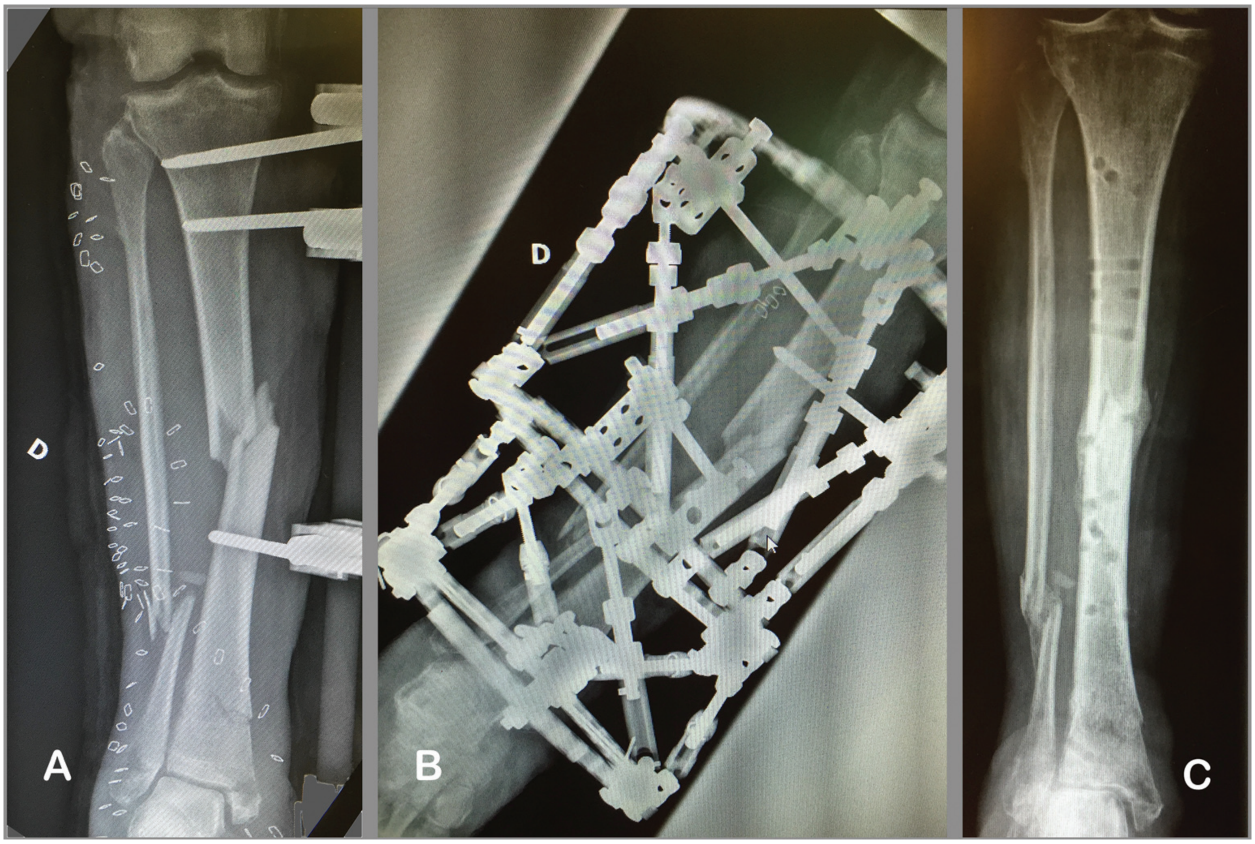

Figure 3. The treatment of an open grade bifocal IIIB fracture in an 82-year-old female. Image A: initial X-ray of the patient who was treated with an external fixation for 3 months, with no callus formation and development of a malunion. The patient required multiple coverage procedures during this period of time. Image B: initial X-ray after the patient was treated with a Taylor Spatial Frame, correction begun. Image C: X-ray after 6 months since the implantation of the TSF. The fracture is healed, good alignment and full soft-tissue coverage is achieved.

The use of computer-assisted orthopaedic devices will help to correct and treat sequelae caused by temporally external fixation (**Figure 3**).

5. Limb salvage or amputation

Most evidence about the decision between limb salvage and amputation is obtained from the lower extremity assessment project (LEAP) study and war-related trauma studies. Several rating scores have been proposed to facilitate the decision, for example, the OTA classification for open fractures, the Mangled extremity severity score or the Ganga Hospital Score [57–60]. Recent publications have demonstrated that these scores should be reviewed to include the new therapeutic advances to prevent amputation and improve the sensitivity and specificity of these scores [61], so these scores alone should not be the only criteria to make our decision.

Because of legal reasons, it is important to include in the clinical records, the anamnesis and graphical documents of the injury, especially in those cases we have decided to perform amputation.

From previous studies, we know that in case of limb conservation, we will face a secondary amputation rate of 3.9%, a complication rate near 40% (10% infections), a 24% non-union rate and an 8% of long-term osteomyelitis. In the case of amputation, we have to consider a reamputation rate of 5.4% and a 25% complication rate in the first 3 months (1/3 infections). At 7 years post-injury, patients treated with amputation or limb salvage procedure were found to have similarly poor outcomes [62], but costs were higher for amputee patients because of the cost of the prostheses [63].

The factors that can modify outcomes, in patients with mangled extremities, are numerous: tobacco consumption is one of the most important, with an increase of 37% in the non-union rate, an increase higher than two times in infection and almost four times in osteomyelitis. Ceasing smoking will improve the union rate, the infection rate and the risk of osteomyelitis, but patients will never have the same risk as a non-smoker. Personal status, education level, gender, age, economic status and patient self-esteem are pre-lesional factors, and worker compensations, depression, SIP score, walking speed, pain and aggressive physiotherapy are post-lesional factor that will modify the outcomes [64–68].

6. Complications

Complication rates in open fractures are dependent on the type of injury. Commonly, we can say that complication rates increase with the Gustilo classification [13, 69]. We can expect a high complication rate for most grade III open fractures, but only a small increase in complications for grade I and II open fractures [69].

For grade I fractures, we can assume a complication rate near close fractures, if they are managed in a proper way, and patients will recover fast [70].

In grade II fractures, the complication rate would be slightly higher than seen in close fractures or grade I [13]. We will appreciate a low increase in the infection rate, and patients would experience a delay in the time until full recovery [70, 71]. In these situations, the use of a plate, if indicated, would not increase the infection rate [71].

In the case of tibial open fractures, from grades IA to IIIA, if they can be managed initially by a nail, with a proper protocol, the complication rate would be similar to close fractures in the first 30 days after the injury [72].

In limb-threatening injuries, if we choose a salvage procedure, we can expect a high complication rate. If we look for the lower extremity assessment project (LEAP) study group outcomes, we will find wound infections in 23% of patients, 31% of non-unions, 5% of malunions and 9% of osteomyelitis [73] in these injuries. These complications would decrease functions in these patients.

Complications would also favor the development of secondary complications, for example, if a patient suffers an infection, he/she will also increase the non-union and delay healing rate (with an odds ratio higher than 4) [74].

7. Conclusions

Open fractures can produce a huge disability in patients. The use of evidence-based protocols and treatments will help us to optimize patient's outcomes. Centers used to manage high-energy trauma with an "orthoplastic" team will achieve the best results in open fractures, specially grade III, and will be prepared to manage the devastating complications that will appear during the reconstructive steps of these fractures.

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Conflict of interest

Authors declare that they do not have conflict of interest.

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