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OPEN FRACTURES: DAMAGE CONTROL, TIMING AND SURGICAL TREATMENT

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ABSTRACT

Open fractures are often caused by high-energy trauma and the trauma itself is a relevant problem in the approach to these fractures. Major trauma may lead to significant long-term morbidity and disability. The fracture itself may induce prolonged illness lasting up to 2 years after the event. Open fractures are defined as bone fractures associated with solution of continuity of the surrounding soft tissue, which puts into communication the external environment and the bone or haematoma derived from the fracture. This communication with the external environment may lead to higher infection rates, malunion and nonunion if not recognised and treated appropriately. Before 1850, most surgeons used to treat open fractures with early limb amputation, since sepsis and gangrene were common side-effects, which often lead to death. It was not until the early twentieth century that sterility techniques became widely accepted, in part thanks to the work of English surgeon Joseph Lister. Known as the father of sterile surgery, Lister was the first to recognise the importance of sterile techniques during surgery. This way, he managed to reduce mortality rates dramatically, from 25–50% to 9%. Today, more than a century later, although open fractures are no longer a cause of mortality, they are still the source of significant morbidity and disability following trauma.

INTRODUCTION

Open fractures are often the result of high-energy trauma and can lead to significant long-term morbidity and disability. An open fracture is defined as a bone fracture associated with the continuity solution of the surrounding soft tissues, which connect the external environment with the bone or the fracture hematoma. This communication with the external environment can lead to higher infection rates compared to unexposed fractures, consolidation delays and pseudoarthrosis if not recognized and properly treated. Before 1850, the majority of the surgeons treated open fractures with early amputation of the limb, since sepsis and gangrene were common consequences, often cause of death. It was only at the beginning of the twentieth century that sterility techniques became widely accepted, thanks also to the work of the English surgeon Joseph Lister. Known as the father of sterile surgery, Lister was the first to recognize the importance of sterile technique during surgery.[1] Using this technique, he achieved a dramatic drop in the mortality rate, from the historical 25 to 50% up to 9%, in his series. Today, more than a century later, although injuries from open fractures no longer cause increased mortality, they continue to be a source of significant morbidity and disability following a trauma.

Epidemiology

Open fractures can result from a large variety of traumas. Common direct mechanisms include high-energy traumas, such as road accidents, gunshots and falls from height. Indirect trauma mechanisms include low-energy torsional lesions, such as those sustained during sports and falls from height. The seriousness of the trauma is directly related to the amount of energy imparted during the injury. The most widely cited classification in orthopaedic literature is the Gustilo and Anderson classification, published for the first time in 1976 and then modified (Table 1). In a follow-up study, Gustilo and collaborators showed that the risk of infection is directly related to the degree of exposure (Fig. 1).[2] At present, the understanding of the importance of soft tissues has led to new classification systems that take into consideration the state of soft tissues both in open and closed fractures. In the latter, it is believed that the degree of compromise of the musculocutaneous envelope is such as to make the prognosis similar to the open fractures (Tables 2, 3).[3] Open fractures occur more frequently in males than in females (7: 3), with a mean age of 40.8 and 56 years, respectively. Hand phalange finger fractures are the most common type, accounting for nearly half of all open fractures with an incidence of 14/100.000 per year in the general population. Fractures of the tibia and distal radius represent the second and third most common open fracture type, with an incidence of 3.4/100.000 per year and 2.4/100.000 per year in the general population, respectively.[4]

Early management of the open fracture

In the managing of polytraumatized patients, including those with open fractures, the most important goal is to save the patient's life. The Advanced Trauma Life Support (ATLS) protocol must be implemented immediately, outside the hospital or in the emergency room. In this case, the polytrauma management protocol foresees resuscitation maneuvers in the first place, followed by an inspection of the patient. Not dwelling on the management of polytrauma, it is important, however, to point out that the management of an open fracture begins at the place where the trauma occurred, in an extra-hospital setting. Based on current recommendations[5], the management of the open fracture calls for the management of any active bleeding and the coverage of the wound with dressings impregnated with not antibiotate saline solution[6], and the application of an occlusive drainage on the wound, without irrigating it. A brace, usually a depression one, must then be placed to immobilize the fracture (Fig. 2). Currently patients with an open fracture are addressed, according to specific protocols, to a Trauma Center that can manage the situation from the ortho-plastic point of view. The open fractures of the hand and any reimplant of the upper limb are instead addressed, according to specific network protocols, in the same region or in neighbouring regions. In the event of major trauma, the Trauma Team is activated before the patient arrives at the hospital, according to the protocols in use in the individual Trauma Centers, while in the case of an isolated lesion of the limb, after confirmation of the patient's stability, the evaluation and orthopaedic management should immediately begin. A systematic inspection of each limb is mandatory. Confirmation of vascular injury is based on definite signs: loss of peripheral pulses, uncontrolled bleeding in the absence of other injury, ever-expanding hematoma. The presence of a positive Doppler signal or capillary refilling are not sufficient signs on their own to exclude vascular injury. The suspected or ascertained presence of a major vascular lesion requires an in-depth diagnostic examination with CT angiography and the emergency treatment of the fracture with a general realignment of the limb obtained by an external fixation and an intervention by the vascular surgeon. In some guidelines, vascular bypass surgery is recommended prior to orthopaedic stabilization, but it is important to note that subsequent limb realignments may compromise the function of a newly performed vascular shunt. If there is no suspicion of a vascular lesion such as to require an emergency intervention, the wounds must be noted and possibly documented for size, position and degree of soft tissue involvement before reduction and/or immobilization. It is extremely important to maintain a high index of suspicion for the compartment syndrome, especially in the context of high-energy trauma. It is wrong to assume that the compartmental syndrome cannot occur in an open fracture. The incidence of the compartment syndrome is directly proportional to the degree of lesion assessed by the Gustilo degree and has been reported up to 9.1% in the open fractures of the tibia.[7] If there is a clinical suspicion of compartment syndrome and the patient is not able to collaborate with the doctor for other traumas, it is necessary to measure the compartmental pressures with appropriate instruments.

Antibiotic prophylaxis

Gustilo and Anderson[8] found that 70% of the wounds were contaminated with bacteria and affirmed that routine use of antibiotics was a therapeutic measure rather than a prophylactic measure. Current recommendations[9] suggest starting antibiotic therapy as soon as possible, within 1 hour of trauma with 1st generation cephalosporins, adding aminoglycosides and antibiotics against anaerobes depending on the degree of contamination.[10]

Debridement

The optimal timing for surgical debridement is controversial. Historically, open fractures have been treated with debridement within 6 hours from the trauma, as reported by Gustilo and Anderson in 1976. Although early studies showed a benefit to early debridement in type II and III open fractures, more recent studies have shown no advantage in performing debridement within 6 hours, provided that antibiotic therapy had been started. Skaggs and collaborators performed a multicenter retrospective study of 554 open fractures in children of a mean age of 8.8 years. All patients received antibiotic therapy upon arrival at the emergency room, while surgical debridement was performed at different intervals from the trauma. Acute infection rates were similar in patients undergoing surgery within 6 hours of trauma compared to those treated for up to 72 hours, regardless of type exposure according to Gustilo.[11] Similarly, Spencer and collaborators performed a 5-year prospective study examining the time effect for surgical debridement on the risk of infection. 103 patients were included in the study with 115 open fractures of long bones. Surgical debridement was performed in less than 6 hours from the moment of trauma in 60% of cases and in more than 6 hours after injury in 40% of cases. Infection rates were 10.1 and 10.8%, respectively, without statistical differences. They concluded that open fractures could be better treated during normal daylight hours by experienced surgeons, without an increased risk of infection, delaying treatment by only a few hours.[12] Recently, a meta-analysis on the effect of time for surgical debridement following open fractures found no statistically significant differences for infections in surgical debridement performed up to 12 hours after the trauma.[13] Current recommendation of international literature suggests that patients with a high rate of contamination of the fracture should be treated in urgency, that is as soon as possible, and are those who classically fall into Gustilo-Anderson's category III C. Open fractures grade II, III A or B can best be treated by a team of experienced surgeons within 12 hours from the trauma and therefore can be sent back to the Trauma list as early in the morning if they arrive at night-time, while the open fracture of grade I can be treated effectively within 24 hours provided that the antibiotic and management protocol of open fractures is respected. Proper debridement is probably the most critical step in preventing infections and achieving fracture healing. The goal is to remove all contaminated and non-vital tissues, including skin, subcutaneous fat, muscles and bones. The wound should be extended longitudinally for proper inspection of the lesion area. The ends of the bone fracture must be inspected, the intramedullary canal cleaned and all the devitalized bone fragments removed, without damaging the soft tissues. Edwards and collaborators found out that removal of necrotic bone significantly reduced the rate of infection in open fractures.[14] Although the vitality of bones and skin is assessed by their ability to bleed, muscle vitality is assessed according to the criteria indicated by Artz and collaborators which consist of the 4 Cs: colour, contractility, consistency and capacity of bleeding.[15] If the vitality of the soft tissues or the adequacy of the debridement is questionable, it is advisable to repeat the debridement. Gustilo in 1990 recommended washing with 5–10 L of normal saline or distilled solution, followed by 2 L of bacitracin solution for all open fractures. More than a decade later, the optimal washing volume has never been established. A recent opinion by Anglen proposed a washing protocol based on the severity of the fracture, with 3 L for type I fractures, 6 L for type II fractures and 9 L for type III fractures. Washing should be performed with normal saline solution. An aspect on which there is still no clear consensus is whether at the time of debridement an antibiotic device must be left in situ. Ostermann and colleagues retrospectively reviewed 1.085 consecutive cases of open fractures, of which 240 received only systemic antibiotics and 845 received systemic antibiotics plus polymethylmethacrylate (PMMA) balls preloaded with tobramycin. The authors observed a significant reduction in the rates of acute infection in type III B and C fractures in the PMMA group. The incidence of local osteomyelitis was also significantly lower in type II and III B fractures in the PMMA group.[16] In addition to the antibiotized cement spheres or to the antibiotized cement spacers positioned on the fracture site, resorbable calcium phosphate-based grafts impregnated with antibiotics have been described. A recent meta-analysis that studies the role of local administration of antibiotics in open tibial fractures has noticed a decrease in the infection rate for all types of Gustilo and, in particular, in type III open fractures.[17]

Orthopedic treatment of open fractures

Early stabilization of the fracture reduces pain, facilitates patient transfers, prevents further soft tissue injuries and promotes healing. This is particularly important for joint fractures, where early mobilization of the joint is certainly beneficial. There are many treatment options for open fractures, depending on the hemodynamic status, the position, type of the fracture and the extent of soft tissue injuries. External fixation is an effective measure of immobilization of the fracture in poly-traumatized patients, particularly in cases of soft tissue defects. However, it can be used not only as a damage control, but also as damage control orthopedics in case the fracture requires a second plastic operation for wound closure, in association with an occlusive bandage or a negative pressure dressing. The advantage of external fixation is that it can also be used, in selected cases, as a definitive treatment of the fracture or to be easily replaced with a definitive fixation device, if correctly positioned. Edwards and collaborators showed a 93% union rate with external fixation at a median follow-up of 9 months in 202 Gustilo type III open tibia fractures.[18] Similarly, in a prospective randomized study of 29 patients with type III B open tibial fractures treated with external fixator and intramedullary nail, Tornetta and collaborators found no differences in terms of healing time, range of motion and infection rate between the two groups.[19] However, compared to external fixation, intramedullary nailing offers the advantage of a higher level of patient compliance. The choice to treat an open fracture of a diaphysis in acute with intramedullary nailing must take into consideration the state of the soft tissues and the clinical situation of the patient. The complications most frequently associated with nailing are respiratory complications (ARDS) and fat embolism syndrome (FES). For both, however, it has been noticed that their incidence was not closely related to the orthopedic intervention, but with trauma and patient characteristics. In particular, regarding the FES, the risk is mainly linked to closed fractures, to young and male subjects, or to patients with multiple fractures. Osteosynthesis with plates and screws is less used for open fractures when they are associated with extensive loss of soft tissue. Comparing the plate fixation and external fixation for type II and III open tibia fractures, Bach and Hansen reported a six-fold increase in the percentage of osteomyelitis.[20] However, new mini-invasive emerged plate osteosynthesis techniques could allow plate fixation to be a viable option in open tibial fractures. In a retrospective analysis of 56 open fractures of extraarticular proximal tibia, Lindvall and collaborators compared the rates of consolidation, pseudarthrosis, mal-reduction, infection and removal of fixation devices between patients treated with percutaneous nail or plate. The open fractures account for 55% (12 of 22) of the nail group and 35% (12 of 34) of the plate group. 4 (33%) of the 12 open fractures in the nail group and 4 (33%) of 12 open fractures in the plate group were infected.[21] If many of the organizational and timing aspects discussed above have been the subject of numerous publications over the years and a consensus in the scientific community was reached, so it has not happened yet about the wound closure of an open fracture. In fact, it has been described in literature how delayed wound closure may increase the risk of infection with Gram-negative nosocomial microorganisms, such as Pseudomonas species, Enterobacter species and Methicillin-resistant S. aureus.

In a randomized double-blind study examining open fractures with adequate soft tissue coverage, Benson and collaborators did not find an increased risk of infection when wound closure was delayed for 5 days in highly contaminated fractures, provided that patients received antibiotic prophylaxis and surgical debridement.[22] For wounds with large loss of substance (type III B and C lesions), Gopal and collaborators favored early internal fixation of the fracture and closure of the wound with a flap within 72 hours. Their conclusion was supported by a higher rate of infection when flap coverage was delayed.[23] Rymer and collaborators, presenting the results of a study on open fractures treated in the hospital, observed that the plastic surgeon was present only in one third of the cases treated at the first surgery. About half of the patients were treated urgently, although, according to the standards described above, only a quarter of them needed these interventions performed at night with non-specialized teams. Despite these findings, about half of the patients underwent definitive orthopedic treatment and soft tissue closure within 72 hours and nearly eighty percent within 7 days. These intervals are those indicated as optimal and suboptimal in other studies. There were non-correctable and correctable reasons for the delay. Among the non-correctable is the presence of a polytrauma that prevents early total care, complex or highly contaminated wounds. The correctable delay was the presence of a plastic surgeon in the initial treatment center and the correct centralization of the patient.[24] The current recommendations of both scientific societies, such as the British Orthopedic Association (BOA) or the NICE, agree in affirming that open fractures, especially of grade II or III, should be centralized in institutions where there is a plastic surgery with trauma experience.[5,25]; the coverage of the wound in a short time seems therefore to be a fundamental point in reducing infections and in general the secondary complications of these patients. There is also a general agreement in stating that the definitive orthopedic treatment must be simultaneous with the definitive closure, with a plastic flap or with non-reconstructive methods, when possible. A factor not extensively studied is wound management with negative pressure wound therapy (NPWT). Some studies dating back to the early years of the decade had hypothesized that the use of NPWT could help reduce infections.[26] Recently the WOLLF clinical trial[27] and the Cochrane review[28] have not demonstrated the superiority of NPWT compared to traditional medication in short and long term results. However, it should be noted that at the moment the same Cochrane review does not report a definitive judgment speaking of mild or moderate evidence in this regard.

CONCLUSIONS

The current management of the open fractures is quite codified. The open fractures in the case of poly-trauma or open fracture as an isolated lesion must be clearly distinguished. In poly-trauma, damage control is essential to save the patient's life and where soft tissue problems follow the famous aphorism "save the life, save the limb, save the function"; in isolated fractures the timing of the famous 6 hours has been re-evaluated and converted into an indication for emergency intervention only in the case of vascular injury or in case of extensive contamination, while type II or III A – B fractures can be operated within 12 hours with a team dedicated to trauma or within 24 hours in case of open type I fractures, without this compromising the functional result, if the antibiotic therapy was started as soon as possible and the acute management of the wound is correct. On the other hand, it appears necessary that these fractures must be centralized and managed in a combined manner, from the first debridement or fasciotomy, together with plastic surgeons, possibly with specific experience. Early wound closure appears to be the real turning point to reduce the complications especially infectious, and not only, of these traumas and improve the quality of life of the people involved.

Conflict of interest: The authors Giacomo Sani, Pietro De Biase, Edy Biancalani and Massimo Sangiovanni declare that they have no conflict of interest.

Informed consent and compliance with ethical standards: All the procedures described in the study that involved human beings were implemented in accordance with the ethical rules established by the 1975 Helsinki declaration and subsequent amendments. Informed consent was obtained from all patients included in the study.

Human and animal rights: The article does not contain any studies performed on humans and animals by the authors.

Table 1: Open fractures classification according to Gustilo and Anderson.

Grade	Definition
I	Open fracture with uncontaminated wound less than 1 cm in length
II	Open fracture, without extensive lesion of soft tissues, flaps, avulsions, with wound between 1 and 10 cm
III	Open fracture with extensive soft tissue injury; traumatic amputation or open segmental fracture. It may include specific categories such as those in the rural environment, with vascular lesions requiring surgical repair or fractures exposed for more than 8 hours before treatment
IIIA	Type III fractures with adequate coverage of the bone even in the presence of extensive soft tissue injury
IIIB	Type III fractures with extensive soft tissue loss and periosteal avulsion and bone lesion (usually associated with severe contamination)
IIIC	Type III fractures associated with arterial vascular injury requiring repair

Table 2: Classification of soft tissue lesions in closed fractures according to Tscherne.

Grade	Energy	Typical fracture pattern	Typical soft tissue damage
C0	Low	Spiral	None to minimal
C1	Mild to moderate	Rotational ankle fracture-dislocations	Superficial abrasion/contusion
C2	High	Transverse segmental complex	Deep abrasions; impending compartment syndrome
C3	High	Complex	Extensive skin contusion; myonecrosis; degloving; vascular injury; compartment syndrome

Table 3: Classification of soft tissue lesions in open fractures according to Tscherne.

Grade	Typical fracture patterns/injuries	Typical fracture pattern
O0	Fractures resulting from indirect trauma	Skin laceration; none to minimal
O1	Fractures resulting from direct trauma	Skin laceration; circumferential contusions; moderate contamination
O2	Comminuted fractures; farming injuries; high-velocity gunshot wounds	Extensive; major vascular and/or nerve damage; compartment syndrome
O3	Subtotal and complete amputations	Extensive; major vascular and/or nerve damage

Fig. 1 - Patient hit by an agricultural vehicle that reported an open fracture of femur and tibia type IIIB according to Gustilo and Anderson

Fig. 2: Realignment of the limb. It is possible to note the preternatural mobility of the limb affected by fracture, in particular a considerable recurvatum of the femur. It is important to realign the fracture limb as soon as possible and stabilize it.

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