ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 9| Issue: 11| November2023|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2023: 8.224 || ISI Value: 1.188

PANORAMIC REVIEW OF OPEN FRACTURES, DESCRIPTION, EPIDEMIOLOGY, ASSESSMENT, CLASSIFICATION, TREATMENT AND COMPLICATIONS

Bryam Esteban Coello García[1], Miguel Sebastián Jiménez Jiménez[2], Víctor Daniel Camacho Iza[3], Diana Marisol Berrezueta Rodríguez[4], Ana Lucía Bustamante Armijos[5], Edgar Geovanny Sandoval Méndez[6], Jaime Leonardo Loja Chicaiza[7], Héctor Manolo Araque Hidalgo[8], Katherine Judith Delgado Solorzano[9], Vanessa Jazmín Mañay Betancourt[10]

[1]Postgraduate Doctor in Orthopedics and Traumatology at Faculdade de Ciências Médicas Minas Gerais. Belo Horizonte - Brasil. ORCID https://orcid.org/0000-0003-2497-0274
[2]General Practitioner in Independent Practice, Faculty of Medical Sciences, Universidad Central del Ecuador. ORCID https://orcid.org/0000-0002-8946-7760
[3]General Practitioner at "Hospital San Francisco", faculty of Medical Sciences, Universidad Central del Ecuador. Ecuador. ORCID https://orcid.org/0009-0001-7726-5643
[4]General Practitioner at "Consultorios Médicos Cruz del Sur Cumbe", faculty of Medical Sciences, Universidad de Cuenca. Cuenca- Ecuador. ORCID https://orcid.org/0000-0001-9639-9869
[5]General Practitioner in Independent Practice, Faculty of Medical Sciences, Universidad de Cuenca. Cuenca- Ecuador. ORCID https://orcid.org/0009-0002-9286-7084
[6]General Practitioner in Independent Practice, Faculty of Medical Sciences, Universidad Católica de Cuenca. Azogues- Ecuador ORCID https://orcid.org/0000-0003-4480-7546
[7]General Practitioner in Independent Practice, Faculty of Medical Sciences, Universidad Católica de Cuenca. Azogues- Ecuador ORCID https://orcid.org/0009-0008-0740-4282
[8]General Practitioner in Independent Practice, Faculty of Medical Sciences, Escuela Superior Politécnica de Chimborazo. Ecuador ORCID https://orcid.org/0009-0006-4413-6817
[9]General Practitioner in Independent Practice, Faculty of Medical Sciences,Universidad Regional Autónoma de los Andes UNIANDES. Ecuador ORCID https://orcid.org/0009-0003-0604-4258
[10]General Practitioner at "Hospital Básico Edgar Arcos", Faculty of Medical Sciences, Universidad Regional Autónoma de los Andes UNIANDES. Ecuador ORCID https://orcid.org/0009-0000-7103-1400

Corresponding Author : *Bryam Esteban Coello García* ***Address:*** *Rua Tiradentes 266.Campo Belo. Minas Gerais. Brasil* ***Postal Code:*** *37270-000*

Article DOI: https://doi.org/10.36713/epra14951
DOI No: 10.36713/epra14951

SUMMARY

Introduction: *An open or exposed fracture is a fracture that has communication with the external environment through a skin wound. Usually these types of severe fractures require treatment by the orthopedic and plastic surgery team to address both bone and soft tissue injuries.*

Objective: *to detail current information related to open fractures, description, epidemiology, evaluation, classification, treatment and complications.*

Methodology: *a total of 33 articles were analyzed in this review, including review and original articles, as well as clinical cases, of which 20 bibliographies were used because the other articles were not relevant to this study. The sources of information were PubMed,*

ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 9| Issue: 11| November2023|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2023: 8.224 || ISI Value: 1.188

Google Scholar and Cochrane; the terms used to search for information in Spanish, Portuguese and English were: exposed fractures, open fractures, acute trauma, compartment syndrome, vascular injury, debridement.

Results: *the general average age of onset is 45.5 years, the incidence decreases in men and increases in women with age. Automobile accidents are the most common cause of open fractures of the lower limbs, accounting for approximately 34.1% of these injuries. The highest incidence of open fractures in males is between 15 and 19 years, the highest incidence in females is between 80 and 89 years.*

Conclusions: *Knowledge of the management of open fractures is of vital importance, due to the fact that this type of fracture presents a high risk of infections, as well as other types of complications. The initial approach to the injured individual with an open fracture should be based on the principles of Advanced Trauma Life Support (ATLS). Clinical and imaging evaluation is important in this type of fracture, as well as recognizing the value of the classification systems that play a critical role when treating surgically. Irrigation and debridement remain the gold standards for proper wound management. The most important point in the treatment of an open fracture is proper lavage and debridement.*

KEY WORDS: *trauma, open fractures, bone exposure, treatment.*

INTRODUCTION

An open or exposed fracture is a fracture that has communication with the external environment through a skin wound. Usually these types of severe fractures require treatment by the orthopedic and plastic surgery team to address both bone and soft tissue injuries. Open fractures are usually high-energy traumatic injuries that commonly occur in traffic accidents, blast injuries in conflict zones and sports. These types of fractures present a high risk of infection, as well as delayed healing, pseudarthrosis and delayed return to function when compared to closed fractures, primarily when not treated correctly. In the management of these fractures, contaminants and non-viable tissue must be removed and the wound closed, becoming closed fractures when the fracture is stabilized. Among some distinctive aspects of severe open fractures are: bone loss, significant bone fragmentation either comminution or segmentation, loss of skin in a way that does not allow a tension-free closure after wound excision and injury to any of the important arteries of the leg(1-3).

METHODOLOGY

A total of 33 articles were analyzed in this review, including review and original articles, as well as cases and clinical trials, of which 20 bibliographies were used because the information collected was not important enough to be included in this study. The sources of information were Cochrane, PubMed and Google Scholar; the terms used to search for information in Spanish, Portuguese and English were: exposed fractures, open fractures, acute trauma, compartment syndrome, vascular injury, debridement.

The choice of bibliography exposes elements related to open fractures; in addition to this factor, description, epidemiology, evaluation, classification, treatment and complications are presented.

DEVELOPMENT

DESCRIPTION

An open fracture is one in which a break in the skin and underlying soft tissues communicates directly with the fracture and its hematoma. One third of individuals with open fractures are polytraumatized. Any wound located in the same segment of the fractured extremity should be considered an open fracture until proven otherwise. Soft tissue injuries in an open fracture usually carry some consequences such as:

Contamination from exposure to the external environment.

Crushing, denudation, lack of vascularization and increased susceptibility to infection.

Loss or destruction of soft tissue coverage, altering immobilization, the contribution of soft tissue to healing and generating functional loss(2,4).

EPIDEMIOLOGY

There are studies showing an incidence of open fractures in adults close to 30.7 per 100,000 people per year. The general average age of onset is 45.5 years, the incidence decreases in men and increases in women with age. Motor vehicle accidents are the most common cause of open fractures of the lower limbs, accounting for approximately 34.1% of these injuries. Crush injuries account for 39.5% of open fractures of the lower extremities. The highest incidence of open fractures in males is between the ages of 15 and 19 years, with approximately 54.5 per 100,000 persons per year, while the highest incidence in females is approximately 53.0 per 100,000 persons per year between the ages of 80 and 89 years. Open phalangeal fractures are the most frequent open fractures, accounting for more than 45% of all open injuries. The most frequent long bone fracture is that of the tibia and fibula in about 11.2%(3,5-7).

ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 9| Issue: 11| November2023|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2023: 8.224 || ISI Value: 1.188

Figure 1. Open fracture involving the carpal bones of the left hand.

Source: The Authors.

MECHANISM OF INJURY

They are usually caused by exerting violent force. Individuals with open fractures have a history of high velocity related trauma. The applied kinetic energy (0.5 mv 2) is dissipated in soft tissue and bone structures. The displacement of bone fragments and comminution guide the level of soft tissue injury, being equivalent to the applied force(2,3).

CLINICAL ASSESSMENT

The initial approach to the injured individual with an open fracture should follow the principles of Advanced Trauma Life Support (ATLS), where life-threatening issues are made known and managed in a logical, hierarchical progression, with the most life-threatening issue being addressed first(1).

1. ABCDE: airway, breathing, circulation, disability and exposure.
2. Resuscitation and treatment of life-threatening injuries.
3. Cranial, thoracic, abdominal, pelvic and spinal injuries must be evaluated.
4. Recognize all injuries present in the extremities.
5. The neurovascular condition of the injured extremities is analyzed.
6. Skin and soft tissue lesions are evaluated: wound examination is not indicated in the emergency room if a surgical intervention is to be performed, due to the increased risk of contamination, also because it can lead to further bleeding and because of its limited ability to provide useful information. Easily accessible foreign bodies should be removed under sterile conditions in the emergency room. Wounds can be washed with sterile physiological saline if it is known to delay pre-intervention time. Intra-articular injection of physiological saline solution using sterile technique may be considered to determine if there is fluid leakage, in addition to assessing for continuity of the lesion.
7. Skeletal lesions are recognized and the necessary radiographs are taken(2,4).

Compartment Syndrome

The presentation of an exposed fracture does not prevent the formation of a compartment syndrome, mostly in crush injuries and major blunt trauma. The main points to be considered for diagnosis are severe pain, reduced sensibility, tension in the limb and pain on passive extension of the fingers. When suspicion

ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 9| Issue: 11| November2023|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2023: 8.224 || ISI Value: 1.188

exists, or in an unconscious individual in appropriate clinical condition, compartment pressures should be monitored. Compartment pressures greater than 30 mm Hg are highly suggestive of compartment syndrome; a difference of less than 30 mm Hg from diastolic blood pressure also indicates the presence of compartment syndrome and urgent fasciotomies should be performed. Distal pulses may be appreciated long after ischemia, nerve injury and muscle injury are not reversible(2-4).

Vascular Injury

The ankle-brachial index (ABI) should be obtained when there are signs of vascular involvement; this is achieved by measuring the diastolic pressure in the ankle and arm; the normal index is greater than 0.9. When a vascular lesion is suspected, angiography is required. Indications for angiography include:

- Cold, pale foot with poor distal capillary filling.
- Knee dislocation with an ITB 0.9.
- High energy injury in a compromised area.
- Documented ITB 0.9 related to a lower limb injury(2,8,9).

IMAGING ASSESSMENT

Radiographic projections of the limbs should be requested depending on the clinical presentation, the pattern of the lesion and the symptoms of the affected individual. At least two orthogonal projections of the limb are recommended. The upper and lower joints of the apparent lesion should be included. When there is intra-articular involvement, it is indicated to complement with a CT scan(2,10,11).

Gustilo and Anderson classification of open fractures

Classically designed to categorize soft tissue injuries related to open diaphyseal fractures of the tibia, however it was later used for all open fractures. Although the description addresses the size of the skin wound, the subcutaneous soft tissue injury is more important because it is directly related to the energy applied to the extremity, which is why definitive classification of the wound should be deferred until after surgical debridement.

Type I: clean skin wound 1 cm, usually from the inside out; minimal muscle contusion; simple transverse or short oblique fracture.

Type II: wound greater than 1 cm in length, with extensive soft tissue injury; minimal to moderate crushing component; simple transverse or short oblique fracture with minimal comminution.

Type III: extensive soft tissue injury, involving musculature, skin and neurovascular structures; usually from high-energy trauma with a significant crushing component.

A: extensive soft tissue injury with adequate bone coverage; segmental fractures, gunshot injuries and minimal periosteal denudation.

B: extensive soft tissue injury with periosteal denudation and bony exposure requiring a soft tissue flap for closure; frequently related to massive contamination.

III C: vascular lesion requiring surgical repair(1,2).

Tscherne's Classification of Open Fractures

It takes into account the size of the wound, as well as the degree of contamination and the mechanism of the fracture. It is divided into the following grades:

I: small puncture wound without associated contusion, insignificant bacterial contamination, low-energy fracture mechanism.

II: small wound, skin and soft tissue contusion, moderate bacterial contamination, variable mechanism of injury.

III: large wound with notable bacterial contamination, extensive soft tissue injury, often related to arterial or nerve injury.

IV: incomplete or complete amputation with variable prognosis depending on the location and nature of the injury.

Tscherne's Classification of Closed Fractures.

Classifies soft tissue injuries in closed fractures and takes into account the type of mechanism, direct versus indirect. It is divided into the following grades:

0: generated by indirect force, with negligible soft tissue injury.

I: closed fracture generated by a low to moderate energy mechanism, with superficial abrasions or soft tissue contusion over the fracture.

II: closed fracture with marked muscle contusion, with deep and possibly contaminated skin abrasions, related to a moderate to high energy mechanism and skeletal injury; high risk of compartment syndrome.

III: extensive soft tissue crushing, with degloving or subcutaneous avulsion and arterial injury or established compartment syndrome(2).

In addition there are other scoring systems created to support the surgeon in deciding whether to cut or maintain a heavily injured lower limb, an example of this would be the Mangled Extremity Severity Score (MESS) described in Table 1(1).

ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 9| Issue: 11| November2023|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2023: 8.224 || ISI Value: 1.188

Table 1. The MESS system.

	Score	Description
Skeletal soft tissue injury	1	Low energy
	2	Moderate energy
	3	High energy
	4	Very high energy
Limb ischaemia, double the score if ischaemia is greater than 6h	1	Pulse reduced or absent but normal perfusion
	2	Pulseless, paresthesia, slow capillary refill
	3	Cold, paralysed, numb
Shock	1	Systolic blood pressure always > 90mmHg
	2	Transient hypotension
	3	Consistent hypotension
Age	1	<30 years old
	2	30 to 50 years old
	3	>50 years old

Source: Johansen K, Daines M, Howey T, Helfet D, Hansen ST. Objective Criteria Predict Accurately Amputation following Lower Extremity Trauma: J Trauma Inj Infect Crit Care (12).

TREATMENT

Treatment in the emergency department.

After the general evaluation of the trauma and the creation of resuscitation measures in case of life-threatening injuries:

1. Clinical and radiological evaluation.
2. Control of hemorrhage by direct compression.
3. Parenteral antibiotic treatment. Prophylactic intravenous antibiotics should be administered within 3 hours of injury or as soon as possible.
4. Assess skin and soft tissue injury.
5. Provisional fracture reduction.
6. Surgical treatment: open fractures are an orthopedic emergency. Early administration of intravenous antibiotics has been shown to reduce the incidence of infection. There is evidence in favor of delaying open fractures for up to 24 hours in the absence of a compromising limb injury. Systematic wound exploration, with lavage and debridement, is necessary prior to definitive fracture fixation. Only easily accessible superficial foreign bodies should be removed. It is important not to wash, debride or explore the wound in the emergency department if early surgery is to be performed, as this may further contaminate the tissues and place detritus deep within the wound. If a delay of more than 24 hours is predicted, a gentle washing with physiological saline is suggested(1,2,4,13-15).

Antibiotic coverage for open fractures

Type I and II fractures: first generation cephalosporins.

Type III fractures: anterior plus an aminoglycoside.

Farm injuries: anterior plus penicillin.

Anti-tetanus prophylaxis should be administered in the emergency area, with a dose of toxoid of 0.5 ml regardless of age; for immunoglobulin, the dose is 75 U in patients 5 years of age, 125 U between 5-10 years of age and 250 U in patients older than 10 years. Both are administered intramuscularly, with different syringes and in different locations(2).

Surgical Treatment

Washing and Debridement

Debridement is the removal of contaminants and non-viable tissue from a wound, which can later become a source of infection. Irrigation and debridement remain the gold standard for proper wound management. The most important point in the treatment of an open fracture is proper lavage and debridement. It is suggested to extend the wound proximally and distally, having the axis of the extremity as the base. Intraoperative cultures are debated and controversial. Debridement should only be done immediately following preoperative treatment if the wound is expected to be contaminated with a high bacterial load, such as sewage or dirt, if there is compartment syndrome, if the arterial supply to the limb is compromised, or if the individual has multiple injuries. For isolated high-energy open fractures, debridement should be performed within 12 h and for low-energy open fractures, within 24 h. Debridement should be performed within 24 h. Debridement should preferably be performed methodically, layer by layer, from superficial to deep and from compartment to compartment(1,2,16).

Large skin flaps should not be implanted because this further devitalizes the tissues supplied by the vertical vessels originating from the fascia. Tendons should be preserved unless they are significantly damaged or contaminated. Bone fragments devoid

ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 9| Issue: 11| November2023|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2023: 8.224 || ISI Value: 1.188

of soft tissue insertions can be removed. Some authors suggest pulsatile lavage, however there is now evidence to support that low pressure, high volume lavage achieves less injury to adjacent tissues with the same effect. Administering antibiotics to the lavage solution has not been shown to be effective. Hemostasis should be performed with care because blood loss can be marked, and clots can form a dead space. In suspicion of compartment syndrome, fasciotomy should be performed(1,2,4,12).

In the past it was recommended that traumatic wounds should not be closed, only the enlargement of the surgical wound was closed. Nowadays, most centers recommend closing the wound after debridement and vacuumassisted closure (VAC), carefully watching for signs or symptoms of sepsis. If the wound is left open, it should be dressed with sterile saline-soaked gauze, a synthetic dressing, a VAC system or an antibiotic dressing. Serial debridement(s) may be performed every 24 h to 48 h, depending on the case, until there is no necrotic soft tissue or bone, and then primary or secondary deferred closure should be performed(2,16).

Foreign Bodies

Possible foreign bodies, both organic and inorganic, must be searched for and removed because they can result in significant morbidity if they remain in the wound, sometimes not applicable to gunshot wounds. Pieces of wood may be within clots and complex to differentiate from muscle. Leather and cloth are often found between wound planes and sometimes away from the site of injury. Emulsifiers such as bisacodyl are sometimes used to remove tar and grease. Foreign bodies induce an inflammatory response, as well as recesses may have pathogenic organisms or spores(2,4).

Fracture Stabilization

Skeletal fixation is necessary to ensure the fracture ends in close apposition and stable to allow osteogenesis. This stability may be absolute or relative to result in primary and secondary bone healing, respectively(17).

Another important factor in fracture healing is the blood supply, which is given through the surrounding soft tissue to the bone, so that soft tissue damage can delay fracture healing. Therefore, when restoring the fracture, it is prudent to minimize damage to the soft tissue and periosteum. In open fractures with extensive soft tissue injury, external fixation is usually preferred over internal fixation. The use of external fixation is usually temporary, to later perform internal fixation, however sometimes it can become definitive treatment(8,18-20).

Figure 2. Fracture Stabilization, with External Fixator

Source: The Authors.

ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 9| Issue: 11| November2023|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2023: 8.224 || ISI Value: 1.188

Definitive internal fixation should only be done when it can be followed immediately by definitive soft tissue coverage to decrease the risk of infection(1).
In open fractures with extensive soft tissue injury, fracture stabilization protects against extra soft tissue injury.

Soft Tissue Coverage and Bone Grafting.
After seeing that there are no areas of necrosis, wound coverage can be performed. The type of coverage depends on the extent and location of the soft tissue injuries. Bone grafting should be done when the wound is clean, closed and dry, the timing for bone grafting after implanting a free flap is controversial.

Figure 3. Subsequent Surgery After Debridement of Open Fracture Using Flap.

Source: The Authors.

Limb Salvage Surgery.
The choice between amputation in Gustilo grade III injuries and limb salvage surgery is controversial. Immediate or early amputation may be indicated when:

- Non-viable limb: irreparable vascular injury, warm ischemia of more than 8 hours, or major crushing with minimal viable tissue.
- When the affected limb puts the life of the affected individual at risk.
- After revascularization, the limb presents a less satisfactory function than that which could be obtained with a prosthesis.
- When the severity of the wound requires multiple surgical interventions and a prolonged reconstruction time incompatible with the personal, sociological and economic consequences bearable for the patient.
- When the affected individual shows an Injury Severity Score (ISS) greater than 20 and saving the limb generates a high metabolic cost or a high necrotic/inflammatory burden that could trigger pulmonary or multi-organ failure(2,4).

COMPLICATIONS

Infection: open fractures can cause cellulitis or osteomyelitis even after several debridements, abundant lavage, adequate antibiotic treatment and conscientious wound care. Some anatomical areas are more prone to infection. Some of the risk factors for infection include extensive contamination at the time of injury, the amount of soft tissue involved, nutritional status, foreign body retention and multisystem injuries.
Undiagnosed compartment syndrome: generates severe functional loss, being more noticeable in the forearm, foot and leg. It can be avoided with good control, performing repeated neurovascular explorations, with the measurement of intracompartmental pressure and through the opening of the fascia(1,2,4,9).

ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 9| Issue: 11| November2023|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2023: 8.224 || ISI Value: 1.188

CONCLUSIONS

Knowledge of the management of open fractures is of vital importance, since this type of fracture presents a high risk of infection, as well as other types of complications. The initial approach to the injured individual with an open fracture should be based on the principles of Advanced Trauma Life Support (ATLS). Clinical and imaging evaluation is important in this type of fracture, as well as recognizing the value of the classification systems that play a critical role when treating surgically. Irrigation and debridement remain the gold standards for proper wound management. The most important point in the treatment of an open fracture is proper lavage and debridement.

BIBLIOGRAPHY

1. *Loh B, Lim JA, Seah M, Khan W. Perioperative management of open fractures in the lower limb. J Perioper Pract. 2022 May;32(5):100–7.*
2. *Koval KJ, Zuckerman JD. Fracturas y luxaciones. 2 ed. Madrid: Marban; 2003.*
3. *Sop JL, Sop A. Open Fracture Management. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 [cited 2023 Nov 6]. Available from: http://www.ncbi.nlm.nih.gov/books/NBK448083/*
4. *Bucholz RW, Heckman JD, Rockwood CA, Green DP. Rockwood & Green's fracturas en el adulto. Madrid: Marbán; 2003.*
5. *Lovalekar M, Abt JP, Sell TC, Lephart SM, Pletcher E, Beals K. Accuracy of recall of musculoskeletal injuries in elite military personnel: a cross-sectional study. BMJ Open. 2017 Dec;7(12):e017434.*
6. *TraumaRegister DGU, Weber CD, Hildebrand F, Kobbe P, Lefering R, Sellei RM, et al. Epidemiology of open tibia fractures in a population-based database: update on current risk factors and clinical implications. Eur J Trauma Emerg Surg. 2019 Jun;45(3):445–53.*
7. *Haeberle HS, Navarro SM, Power EJ, Schickendantz MS, Farrow LD, Ramkumar PN. Prevalence and Epidemiology of Injuries Among Elite Cyclists in the Tour de France. Orthop J Sports Med. 2018 Sep;6(9):232596711879339.*
8. *Rommens PM, Broos PL. The significance of soft tissue trauma for fracture healing. A prospective study on 70 tibial shaft fractures following primary treatment with the Monofixateur. Unfallchirurg. 1992 Mar;95(3):133–41.*
9. *Nogueira Giglio P, Fogaça Cristante A, Ricardo Pécora J, Partezani Helito C, Lei Munhoz Lima AL, dos Santos Silva J. Advances in treating exposed fractures. Rev Bras Ortop Engl Ed. 2015 Mar;50(2):125–30.*
10. *Santos ADL, Nitta CT, Boni G, Sanchez GT, Tamaoki MJS, Reis FBD. EVALUATION AND COMPARISON OF OPEN AND CLOSED TIBIA SHAFT FRACTURES IN A QUATERNARY REFERENCE CENTER. Acta Ortopédica Bras. 2018 Jun;26(3):194–7.*
11. *Oliveira RV, Cruz LP, Matos MA. Comparative accuracy assessment of the Gustilo and Tscherne classification systems as predictors of infection in open fractures. Rev Bras Ortop Engl Ed. 2018 May;53(3):314–8.*
12. *Johansen K, Daines M, Howey T, Helfet D, Hansen ST. Objective Criteria Accurately Predict Amputation following Lower Extremity Trauma: J Trauma Inj Infect Crit Care. 1990 May;30(5):568–73.*
13. *M[illegible]'Bra KI, Kouassi AAN, Niaore Sery BJL, Yao LB, Kouassi KJE, Jr Ochou PG, et al. Amputations secondaires du membre après une chirurgie primaire des fractures ouvertes du membre inferieur. Pan Afr Med J [Internet]. 2018 [cited 2023 Nov 6];29. Available from: http://www.panafrican-med-journal.com/content/article/29/172/full/*
14. *Conaty O, Gaughan L, Downey C, Carolan N, Brophy MJ, Kavanagh R, et al. An interdisciplinary approach to improve surgical antimicrobial prophylaxis. Int J Health Care Qual Assur. 2018 Mar 12;31(2):162–72.*
15. *Noblet TM, Jackson PC, Foster P, Taylor DM, Harwood PJ, Wiper JD. Managing soft tissues in severe lower limb trauma in an ageing population. Injury. 2018 Jun;49(6):1197–202.*
16. *Gupta R, Sharma AR, Singhal A, Shail S, Masih GD. Concepts in wound irrigation of open fractures: 'Where we came from, and where are we now? J Clin Orthop Trauma. 2021 Dec;23:101638.*
17. *Sathyendra V, Darowish M. Basic Science of Bone Healing. Hand Clin. 2013 Nov;29(4):473–81.*
18. *Beltsios M, Savvidou O, Kovanis J, Alexandropoulos P, Papagelopoulos P. External fixation as a primary and definitive treatment for tibial diaphyseal fractures. Strateg Trauma Limb Reconstr. 2009 Oct 31;4(2):81–7.*
19. *Marsh DR, Li G. The biology of fracture healing: optimising outcome. Br Med Bull. 1999 Jan 1;55(4):856–69.*
20. *Jordan DJ, Malahias M, Khan W, Hindocha S. The Ortho-Plastic Approach to Soft Tissue Management in Trauma. Open Orthop J. 2014 Oct 31;8(1):399–408.*

Conflict of Interest Statement

The authors report no conflicts of interest.

Funding

The authors report no funding by any organization or company.