Treatment of open tibia fractures in Sub-Saharan African countries: a systematic review

Kouamé Jean-Eric Kouassi[1] · Julie Manon[1] · Loic Fonkoué[1] · Christine Detrembleur[1] · Olivier Cornu[1,2]

[1] Experimental and Clinical Research Institute (IREC), Neuro-Musculo-Skeletal Pole (NMSK), Université catholique de Louvain, Tour Pasteur +4, 53 avenue Emmanuel Mounier, 1200 Brussels, Belgium

[2] Department of Orthopedics and Trauma, Cliniques universitaires Saint-Luc, Université catholique de Louvain, Avenue Hippocrate 10, 1200 Brussels, Belgium

Corresponding author:

Kouamé Jean-Eric Kouassi

Unité de recherche NMSK – IREC – Université catholique de Louvain

Tour Pasteur +4 – 53 avenue Emmanuel Mounier

1200 Bruxelles

Belgium

E-mail: medericko@yahoo.fr

Phone: +32 2764 2994

Fax: +32 2 764 8904

Abstract

Introduction Open tibia fracture (OTF) treatment is well documented in developed countries. Yet, this fracture pattern remains challenging because it is associated with an increased risk of infection and delayed union, particularly in case of Gustilo III B and C open fractures. Since access to healthcare is limited in Sub-Saharan African countries, this paper explores the results of OTF management in this setting.

Materials and methods A systematic review of the literature was conducted using current databases such as MEDLINE, Cochrane, EMBASE, PubMed, ScienceDirect, Scopus, and Google Scholar in order to identify prospective studies with cohorts of patients treated for OTF. Studies were included based on predefined inclusion and exclusion criteria. The quality of studies was analyzed by the Coleman Methodology Score (CMS).

Results Eight papers met the inclusion criteria and had an average CMS of 70 (range 54–73). The most common treatment was non-operative management of the fracture with cast immobilization (67%). Gustilo Type II and III fractures were associated with a higher risk of complications. The infection rate was 30%. Malunion, chronic osteomyelitis and nonunion were observed in 14.5%, 12.3%, and 7% of the cases, respectively. More complications were observed with non-operative treatment (cast immobilization) than with surgical fixation.

Conclusions Although the surgical environment does not allow for internal fixation, poor results of non-operative management of open fractures should lead to the introduction of trainings on the proper use of external fixators. It is also advisable to support the development of locally produced external devices that utilize local source materials, which would make external fixation available at a reasonable cost.

Keywords Africa · Cast immobilization · Developing countries · Open fracture · Tibia

Introduction

Open tibia fracture (OTF) treatment is well documented in developed countries and the management principles of open fractures are well established [1]**.** Yet, this fracture pattern remains challenging, as it is associated with an increased risk of infection and delayed union, particularly in case of Gustilo III B and C open fractures [2–4]. Since poor urban populations in Sub-Saharan African countries have limited access to healthcare [5], the difficulties of treatment are multifactorial. Patients experience delays in surgical management that are related to their socioeconomic conditions and the absence of an efficient system to transfer the wounded to hospitals. Limited technical plateaus, lacking fixation hardware, and insufficient training in soft-tissue reconstruction techniques are also frequently reported [5–8]. We therefore wish to examine the results of OTF management in this setting by performing a literature review. The aims of this systematic review were 1) to assess the published literature on OTF in Sub-Saharan African countries, 2) to identify management strategies that have been applied, and 3) to evaluate the complication rate of these fracture stabilization methods. Poorer results were expected as compared to those observed in developed countries.

Methods

The systematic review protocol complied with the guidelines provided by the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) statement [9].

Literature search

Keywords were identified using the PICO method in relation to the population (open tibial fracture OR developing countries OR Africa), the intervention (external fixators OR nails OR plaster of Paris), and outcomes (union OR malunion, OR, nonunion OR infection). The search was performed on articles dated between 2000 and October 2019, using several electronic databases: PubMed, Google Scholar, ScienceDirect, EMBASE, Scopus, the Cochrane Library, and additional African Journals. All references were exported from the databases to Endnote.

Study selection

We selected available studies that were conducted in Sub-Saharan African countries. Articles meeting the following criteria were included: the reported language was English or French, the study was prospective, the study investigated populations of at least 20 patients, demographic data was included and the well-described treatment regimen was available, the Gustilo-Anderson classification was used [10], methods of fracture stabilization were identified, union and complications were described. Articles were excluded if they did not meet the above inclusion criteria, if they related to a neglected OTF, or if the study was retrospective or a case report.

Two researchers (KE, CD) independently screened the titles and abstracts of the retrieved studies to assess eligibility, after duplicates were removed. Articles that met the inclusion criteria were selected for a full-text lecture, and corresponding authors were contacted when the full text was not available. Articles that met the inclusion criteria were also included for qualitative synthesis. Disagreements were resolved through consensus.

Quality assessment

Two authors independently scored the quality of the studies using the Coleman Methodology Score (CMS) [11, 12], which was adapted (Table 1) to evaluate studies reporting on OTF. The CMS is a method of analyzing the quality of studies being reviewed by assessing the methodology using 10 criteria, giving a total score between 0 and 100. A score approaching 100 indicates that the study has a robust design and largely avoids chance, various biases, or confounding factors. A score >85 is considered excellent, 70–84 is good, 50–69 is moderate, and <50 is poor. The CMS's subsections are based on the subsections of the Consolidated Standards of Reporting Trials (CONSORT) statement (for randomized, controlled trials) [13].

Data extraction and synthesis

Two authors (KE, CD) extracted data using a pre-pilot standardized form (Table 2), which included the first author's last name, publication year, CMS number, demographic data, diagnosis (fracture pattern), the Gustilo grade of the open fracture, interventions, and any complications (infection, malunion, nonunion).

Statistical analysis was performed using SigmaPlot version 13. We calculated the median and quartile [25-75] of the outcomes. The risk of developing a complication was also determined according to the stabilization method and the Gustilo type of open fracture.

Results

The electronic search yielded 2,651 articles, but only eight met the inclusion criteria and were considered eligible for the study (Fig. 1). The average CMS was 70.5 (range 54–73), which is indicative of good methodological quality [11]. The eight studies [14–21] reported on 641 patients who were treated for an OTF. Their mean age was 34 years (range 33–36), with 77% males. The mechanism of injury was road traffic accident (RTA) in 85.3% [14–21]. Fractures were predominantly in the middle third (62.8%), followed by the distal third (36%) [15–17, 20, 21]. The comminuted fracture pattern was the most frequent (46.4%), followed by transverse (28.9%) and oblique fractures (25%) **[**14–17, 20, 21**]**.

Gustilo II and III fractures accounted for 42.6% and 30.2% of cases, respectively. Regarding the time from injury to operation, 76.6% of patients were operated on within 24 hours [15, 17, 19].

Open wound management was described in all studies, but numerical data was only available in four studies [17, 19–21]. Skin grafting was used in 44.07%, primary closure in 21.3%, and flap coverage in only 8.5%. Secondary healing was expected in 10.8%. Several techniques were used for fracture stabilization in seven studies [14, 15, 17, 19–21], while one reported only external fixators (ExFx) [16] and another exclusively intramedullary nailing [18]. Cast immobilization (CI) was solely used for fracture fixation in 67.1% of cases (Fig. 2). Primary amputation was performed in 7.7% of patients [14, 20] and secondary amputation was performed in 2.3% of patients [15]. Fracture healing was reported after a mean delay of 20.6±4.4 weeks. The union rate was 58.9% [14–21]. Fig. 3 summarizes the pooled data regarding complication rates. Infections were frequent (30%), and non-operative treatment/CI was associated with an increased complication rate when compared to surgical fixation (Fig. 4).

Discussion

OTF management is a significant cause for concern in developing countries [22]. OTFs are usually associated with a high complication rate [23], particularly infection, malunion, and nonunion [24]. With regards to the complications observed, the average incidence of infections was 30%. This overall infection rate is higher than the rates reported in some studies [25–27], but similar to others [23, 28–30]. The high proportion of Gustilo III fractures in this series may explain the poorer results, although a systematic review of open Gustilo III B and C fractures reported lower infection rates [4]. Better results might be expected in middle-income [25] or developed countries [31].

Delayed treatment has been proposed as a potential cause of infection. However, Reuss and Cole reported that delayed operative management of up to 48 hours did not adversely affect infection rates [32]. The timing for soft-tissue coverage is also controversial, as some advocate early flap coverage [33] and others advocate delayed wound closure [34]. It has been observed that flap coverage within 72 hours reduced infection rates [3], and, for Gustilo III B fractures, soft-tissue coverage within (versus after) one week resulted in lower rates of infection (8% versus 59%) [35]. It is not possible to confirm that the choice of secondary soft-tissue healing in our review negatively influenced the result.

The average incidence of nonunion was lower than the rates reported in some studies [28, 31]. With regards to malunion, the average incidence was higher than the rates reported in the existing literature [36]. The predominant use of CI in place of modern surgical fixation in our series could explain these outcomes. However, the results are not fully comparable, due to differences in the methods used for fracture stabilization.

Early stabilization is of paramount importance and, ideally, should be performed at the time of the initial debridement. This restores limb alignment, eliminates gross movement at the fracture site, limits further soft-tissue damage, and decreases the risk of further bacterial spread [37].

The types of fixation currently available are ExFx, plates and screws, reamed and unreamed locking nails, and CI [38–40]. However, specific problems are inherent to each treatment method, which means every method is less than ideal [24].

Methods of fracture stabilization varied between studies. The CI was the most used because it is cheap, readily available and non-invasive [21, 41]. Access to the wound unfortunately remains difficult for inspection and dressing. Windows made on the CI often weaken it and compromise adequate maintenance of fracture reduction [21]. Prolonged CI application caused joint stiffness, quadricep wasting, and secondary fracture displacement [21, 40].

The potential advantages of ExFx include minimal soft-tissue stripping, as well as easy and quick application in emergency situations [42]. The disadvantages, however, include track problems with the pins, reduction loss, and the potential for fracture from the pin track site [24, 43].

The potential advantages of intramedullary nailing include improved cosmesis, early mobilization, and stable reduction [21]. Its disadvantages include the potential for deep infection (osteomyelitis) and the spread of infection through the medullary canal [44].

Postoperative infection rates are a major indicator of the viability of a particular surgical modality. In this series, the rates of infections and postoperative complications were higher with the use of plaster as a method of immobilizing fractures. This outcome was similar to that found in other studies [15, 19].

We believe that, in Sub-Saharan African countries, economic constraints favor CI as a method of treatment for these fractures. CI is cheaper than ExFx or an intramedullary nail and removes any need for special instrumentation or intraoperative image intensifiers. We believe that local development of a low-cost ExFx [43] could provide an alternative to CI and ExFx devices that are available in developing country markets, since ExFx continues to be an acceptable modality of management in developing countries, where patients arrive late to hospitals and where local medical facilities are poorly available [21]. ExFx is technically less demanding and requires no specialized equipment [22, 21]. Although initial union rates may be lower with external fixation compared to intramedullary nailing, these fractures ultimately unite, even if the union time is prolonged [45]. Finally, applying an ExFx to the initial injury may also decrease the ultimate rate of infections and osteomyelitis, which is considerably more debilitating and morbid than the trauma of repeat surgery that is secondary to a nonunion.

Limitations and future perspectives

Some differences can be noted in the eight studies selected, which makes it difficult to compare and generalize results. First, the inclusion criteria were not the same. Second, the therapeutic attitude was not standardized because the methods of restraint were varied. Finally, details of antibiotic administration were not well described in most of the studies.

However, this study does present a prospective collection of surgical data and, where possible, reveals how this data compares favorably to other studies in the literature.

Despite the limitations of our study, we recommend the local development of a new, low-cost ExFx. We also recommend promoting trainings on the proper use of techniques for early and adequate soft-tissue coverage by orthopedic surgeons. Additionally, we propose employing a score that measures quality of life with good psychometric properties, such as SF-36 [46] or the lower extremity functional scale (LEFS) [47].

Conclusion

This review reveals that OTFs mainly concern young male subjects. The main cause is RTAs involving motorcycles. Fractures were essentially comminuted, and CI was mostly used as the method for fracture stabilization. The treatment of OTFs in this setting was associated with a high rate of complications, particularly when the fracture was managed non-operatively with CI. New low-cost ExFx implant designs and adequate soft-tissue cover (muscle flaps) could help improve treatment of OTFs in developing African countries.

References

1. Camuso M, Colton C (2012) Principes de gestion des fractures ouvertes. Référence de chirurgie AO. https://www2.aofoundation.org/. Accessed 22 Dec 2019.

2. Gustilo RB, Mendoza RM, Williams DN (1984) Problems in the management of type III severe open fractures: a new classification of type III open fractures. J Trauma 24:742–746. https://doi.org/10.1097/00005373-198408000-00009

3. Singh A, Jiong Hao JT, Wei DT, Liang CW, Murphy D, Thambiah J, Han CY (2018) Gustilo IIIB Open Tibial Fractures: An Analysis of Infection and Nonunion Rates. Indian J Orthop 52:406–410. https://doi.org/10.4103/ortho.IJOrtho_369_16

4. Saddawi-Konefka D, Kim HM, Chung KC (2008) A systematic review of outcomes and complications of reconstruction and amputation for type IIIB and IIIC fractures of the tibia. Plast Reconstr Surg 122:1796–1805. https://doi.org/10.1097/PRS.0b013e31818d69c3

5. Mathieu L, Mottier F, Bertani A, Danis J, Rongiéras F, Chauvin F (2014) Management of neglected open extremity fractures in low-resource settings: Experience of the French Army Medical Service in Chad. Orthop Traumatol Surg Res 100:815–820. https://doi.org/10.1016/j.otsr.2014.06.017

6. Dada AA, Yinusa W, Giwa SO (2011) Review of the practice of traditional bone setting in Nigeria. Afr Health Sci 11:262–265. https://doi.org/10.4314/ahs.v11i2.68455

7. Ikem IC, Oginni LM, Bamgboye EA (2001) Open fractures of the lower limb in Nigeria. Int Orthop 25:386–388. https://doi.org/10.1007/s002640100277

8. Museru LM, Mcharo CN (2002) The dilemma of fracture treatment in developing countries. Int Orthop 26:324–327. https://doi.org/10.1007/s00264-002-0408-7

9. Moher D, Liberati A, Tetzlaff J, Altman DG; PRISMA Group (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med 6:e1000097. https://doi.org/10.1371/journal.pmed.1000097

10. Gustilo RB, Merkow RL, Templeman D (1990) The management of open fractures. J Bone Joint Surg Am 72:299–304.

11. Coleman BD, Khan KM, Maffulli N, Cook JL, Wark JD (2000). Studies of surgical outcome after patellar tendinopathy: clinical significance of methodological deficiencies and guidelines for future studies. Victorian Institute of Sport Tendon Study Group. Scand J Med Sci Sports 10:2–11. https://doi.org/10.1034/j.1600-0838.2000.010001002.x

12. Tallon C, Coleman BD, Khan KM, Maffulli N (2001) Outcome of surgery for chronic Achilles tendinopathy. A critical review. Am J Sports Med 29:315–320. https://doi.org/10.1177/03635465010290031101

13. Moher D, Schulz KF, Altman DG; CONSORT (2001) The CONSORT statement: revised recommendations for improving the quality of reports of parallel group randomized trials. BMC Med Res Methodol 1:2. https://doi.org/10.1186/1471-2288-1-2

14. Enweluzo GO, Adekoya-Cole TO, Mofikoya BO, Giwa SO, Badmus OO (2015) Morbidity of Open Tibia Fractures in Lagos, Nigeria. East Cent African J Surg 20:37–43.

15. Kouassi KJE, Manon J, Fonkoue L, Kodo M, Detrembleur C, Cornu O (2019) Is the management of open leg fractures in a hospital facility in Ivory Coast a problem and why? Rev Chir Orthop Trauma 105:654–658 [French].

16. Abang IE, Asuquo JE, Anisi CO, Mpama EA, Onuba OO, Udosen AM, Ngim NE, Ikpeme IA (2018) Early Outcome of Treatment of Open Tibial Shaft Fractures Using External Fixators in Resource-Poor Setting. Recent Adv Biol Med 4:1–9. https://doi.org/10.18639/RABM.2018.04.458101

17. Touré L, Diallo M, Traoré T, Sidibé O, Dembélé M, Hans-Moevi A (2018) Traitement des fractures ouvertes de jambe dans un hôpital de seconde référence. J Afr Chir Orthop Traum 3:8–14.

18. Handy ED, Samba K, Bang GA, Touré S, Jean Emile B, Ngo Nonga B, Agoh S, Sosso MA (2017) Osteosynthesis by Centromedullary Nailing of Open Fractures: Proceding, Results and Indications. Rev Int Sc Med 19:206–211[French].

19. Tolgou Y, Ofori A, Holdbrook-smith H, Wegdam H (2017) Treatment outcome of open tibial shaft fractures in a teaching hospital in Ghana. Postgrad Med J Ghana 6:47–53.

20. Ifesanya AO, Omololu AB, Ogunlade SO, Alonge TO (2010) The burden of open fractures of the tibia in a developing economy. Nig J Plast Surg 6:32–9. https://doi.org/10.4314/njpsur.v6i1.53593

21. Ikem IC, Oginni LM, Ogunlusi JD (2006) Determinants of management outcome in open tibia fractures in ile-ife. Nig J Surg Res 8:81–83. https://doi.org/10.4314/njsr.v8i1.54845

22. Mathieu L, Potier L, Ndiaye R, Mbaye E, Sene M, Faye M, Niang CD (2019) Management of Gustilo type IIIB open tibial shaft fractures with limited resources: experience from an African trauma center. Eur J Trauma Emerg Surg [Epub ahead of print]. https://doi.org/10.1007/s00068-019-01223-0

23. Lua J, Tan VH, Sivasubramanian H, Kwek E (2017) Complications of open tibial fracture management: risk factors and treatment. Malays Orthop J 11:18–22. https://doi.org/10.5704/MOJ.1703.006

24. Bali K, Aggarwal S, Kumar V, Mootha A, Rawall S, Tahasildar N, Dhillon M (2011) Operative management of type II and type IIIa open tibial fractures presenting from 6-24 hours after injury: an Indian experience. Current Orthop Practice 22:262–266. https://doi.org/10.1097/BCO.0b013e31821374ba

25. Schade AT, Hind J, Khatri C, Metcalfe AJ, Harrison WJ (2020) Systematic review of patient reported outcomes from open tibia fractures in low and middle income countries. Injury 51:142–146. https://doi.org/10.1016/j.injury.2019.11.015

26. Kamat AS (2011) Infection rates in open fractures of the tibia: is the 6-hour rule fact or fiction? Orthop Adv 1–4. https://doi.org/10.4061/2011/943495

27. Alhammoud A, Maaz B, Alhaneedi GA, Alnouri M (2019) External fixation for primary and definitive management of open long bone fractures: the Syrian war experience. Inter Orthop 43:2661–2670. https://doi.org/10.1007/s00264-019-04314-0

28. Yusof NM, Khalid KA, Zulkifly AH, Zakaria Z, Amin MA, Awang MS, Ahmad AC, Akter SF (2013) Factors associated with the outcome of open tibial fractures. Malays J Med Sci 20:47–53.

29. Khatod M, Botte MJ, Hoyt DB, Meyer RS, Smith JM, Akeson WH (2003) Outcomes in open tibia fractures: relationship between delay in treatment and infection. J Trauma 55:949–954. https://doi.org/10.1097/01.TA.0000092685.80435.63

30. Chua W, Murphy D, Siow W, Kagda F, Thambiah J (2012) Epidemiological analysis of outcomes in 323 open tibial diaphyseal fractures: a nine-year experience. Singapore Med J 53:385–389.

31. Young S, Lie SA, Hallan G, Zirkle LG, Engesaeter LB, Havelin LI (2013) Risk factors for infection after 46,113 intramedullary nail operations in low- and middle-income countries. World J Surg 37:349–355. https://doi.org/10.1007/s00268-012-1817-4

32. Reuss BL, Cole JD (2007) Effect of delayed treatment on open tibial shaft fractures. Am J Orthop 36:215–220.

33. Naique SB, Pearse M, Nanchahal J (2006) Management of severe open tibial fractures: The need for combined orthopaedic and plastic surgical treatment in specialist centres. J Bone Joint Surg Br 88:351–357. https://doi.org/10.1302/0301-620X.88B3.17120

34. Russell GG, Henderson R, Arnett G (1990) Primary or delayed closure for open tibial fractures. J Bone Joint Surg Br 72:125–128.

35. Caudle RJ, Stern PJ (1987) Severe open fractures of the tibia. J Bone Joint Surg Am 69:801–807.

36. Milenković S, Mitković M (2018) External Fixation of Extra-Articular Open Tibial Fractures. Acta Facultatis Med Naissensis 35:330–336. https://doi.org/10.2478/afmnai-2018-0035

37. Worlock P, Slack R, Harvey L, Mawhiney R (1994) The prevention of infection in open fractures: an experimental study of the effect of fracture stability. Injury 25:31–38. https://doi.org/10.1016/0020-1383(94)90181-3

38. Keating JF, Blachut PA, O'Brien PJ, Court-Brown CM (2000) Reamed Nailing of Gustilo Grade IIIB Tibial Fractures. J Bone Joint Surg Br 82:1113–1116. https://doi.org/10.1302/0301-620x.82b8.10566

39. Giannoudis PV, Papakostidis C, Roberts C (2006) A review of the management of open fractures of the tibia and femur. J Bone Joint Surg Br 88:281–289. https://doi.org/10.1302/0301-620X.88B3.16465

40. Toivanen JA, Honkonen SE, Koivisto AM, Järvinen MJ (2001) Treatment of low-energy tibial shaft fractures: plaster cast compared with intramedullary nailing. Int Orthop 25:110–113. https://doi.org/10.1007/s002640000083

41. Twagirayezu E, Dushimiyimana J, Bonane A (2008) Open fractures I Rwanda: The Kigali experience. East Central Afri J Surg 13:77–84.

42. Sellei RM, Kobbe P, Dienstknecht T, Lichte P, Pfeifer R, Behrens M, Brianza S, Pape HC (2015) Biomechanical properties of different external fixator frame configurations. Eur J Trauma Emerg Surg 41:313–318. https://doi.org/10.1007/s00068-014-0436-1

43. Hao ZC, Xia Y, Xia DM, Zhang YT, Xu SG (2019) Treatment of open tibial diaphyseal fractures by external fixation combined with limited internal fixation versus simple external fixation: a retrospective cohort study. BMC Musculoskelet Disord 20:311. https://doi.org/10.1186/s12891-019-2679-9

44. Hofmann A, Dietz SO, Pairon P, Rommens PM (2015) The role of intramedullary nailing in treatment of open fractures. Eur J Trauma Emerg Surg 41:39–47. https://doi.org/10.1007/s00068-014-0485-5

45. Alberts KA, Loohagen G, Einarsdottir H (1999) Open tibial fractures: faster union after unreamed nailing than external fixation. Injury 30:519–523. https://doi.org/10.1016/s0020-1383(99)00143-6

46. Bullinger M (1995) German translation and psychometric testing of the SF-36 health survey: preliminary results from the IQOLA project. International quality of life assessment. Soc Sci Med 41:1359–1366. https://doi.org/10.1016/0277-9536(95)00115-n

47. Mehta SP, Fulton A, Quach C, Thistle M, Toledo C, Evans NA (2016) Measurement Properties of the Lower Extremity Functional Scale: A Systematic Review. J Orthop Sports Phys Ther 46:200–216. https://doi.org/10.2519/jospt.2016.6165

Fig. 1 Flowchart of study selection

Fig. 2 Box plot showing distribution of fracture stabilization methods

Fig. 3 Box plot showing distribution of complication rates

Fig. 4 Trend curve of complications according to restraint methods

Table 1 Criteria used to compute the Coleman Methodology Score for studies reporting on open tibia fracture outcomes

S.no.	**Part A: only one score to be given for each of the seven sections**		Score
1	Study size—number of TARs	<20	0
		20-49	4
		50-99	7
		>99	10
2	Mean follow-up	<1 year	0
		1-2 years	4
		2-5 years	7
		>5 years	10
3	Number of different fracture stabilization techniques used	Not stated, unclear, or <90% of subjects receiving same technique	0
		More than one techniques, but >90% of subjects receiving one technique	7
		One technique used	10
4	Type of study	Retrospective cohort study	0
		Prospective cohort study	10
		Randomised control trial	15
5	Description of indications/diagnosis (e.g. fracture grade)	No	0
		Yes	5
6	Descriptions of surgical technique	Inadequate (not stated, unclear)	0
		Fair (technique only stated)	3
		Adequate (technique stated, details of surgical procedure given)	5
7	Postoperative management described	No	0
		Yes	10
	Part B: scores may be given for each option in each of the 3 sections if applicable		
1	Outcome criteria	Outcome measures clearly defined	2
		Timing of outcome assessment clearly stated	2
		Use of outcome criteria that has reported reliability	3
		General health measure included	3
2	Procedure of assessing outcomes	Subjects recruited	5
		Investigator independent of surgeon	4
		Written assessment	3
		Completion of assessment by patients themselves with minimal investigator assistance	3
3	Description of subject selection process	Selection criteria reported and unbiased Recruitment rate reported	5
		<90%	0
		>90%	5

Table 2 Summary of patient characteristics - demographics, protocol, treatment outcome

Author **Year [ref]** **Score (CMS)**	**Patients: n** **Men/women (%)** **mean age±SD** **major cause (RTA) (%)**	**Location** **(%)** **Pr** **Mi** **Di** **Eph**	**Fracture** **pattern** **(%)** **Co** **Tra** **Ob** **Seg** **Spi**	**Time from** **injury to** **presentation**	**Mean time** **from injury to** **operation**	**Gustilo (%)** **I** **II** **III**	**Methods of** **fracture** **stabilization (%)** **EF** **IN** **CI** **P** **AMP**	**Outcome (%)** **IF** **NU** **MU** **OS**	**Union (%)** **Mean time to union**
Enweluzo et al. 2015 [14] 76/100	n=197 73.6/26.4 36.9 ±18.9 RTA=78.2	NA	Co=11.2 Tra=32 Ob=47.2 Seg=5.6 Spi=4.1	NA	NA	I=26.4 II=49.2 III=24.4	EF=10.2 IN=13.2 CI=71.7 P=4 AMP=2	IF=22.3 NU=3 MU=6.6 Death=0.5	65.5

Kouassi et al. 2019 [15] 54/100	n=43 88.3/11.7 33.3±14.1 RTA=93.1	Mi=62.8 Ep=37.2	Co=69.7 Tra=30.3	NA	>24h=48.8 ≤24h=51.2 Mean=27h	I=11.7 II=58.1 III=30.2	EF=23.2 IN=14 CI=62.8 AMP=2.3	IF=51.2 NU=7 MU=39.5 OS=18.6	34.49 25 weeks
Abang et al. 2018 [16] 69/100	n= 40 75/25 33.5 ± 12.8 RTA:95	Pr=10 Mi=32.5 Di=57.5	Co=52.5 Tra=5 Ob=25 Seg=12.5 Spi=5	NA	NA	II=15 III=85	EF=100	IF=82.5	32.5
Touré et al. 2018 [17] 73/100	n=58 91.3/8.7 32 RTA=93.1	Pr=13.8 Mi=63.8 Di=22.4	Ob=19.1 Tra=66.1 Spi=7.4		≤24h=81 >24h=19 Mean=10h	I=24 II=55 III=21	EF=52 IN=31.4 CI=11 P=5.6	IF=35 NU=8.6 MU=27.8	91 16weeks
Handy et al. 2017 [18] 72/100	n=69 78/ 22	NA	NA	NA	Mean=72h	I=26 II=61 III=13	IN =100	IF=8.7 OS=4.3	87 20weeks

	37.48 RTA=74								
Tolgou et al. 2017 [19] 54/100	n=47 85/15 34.6 RTA=87.7	NA	NA	≤24h=89.3 >24h=10.7	≤24h=76.6 >24h=23.4	I=11 II=36 III=53	EF=68.1 IN=2.1 CI=29.8	IF=25 MU=16.7 OS=8.3 Death=8.3	74.47
Ifesanya et al. 2010 [20] 52/100	n=98 70/ 30 33.3±14.8 RTA=83	Pr=9.2 Mi=76.5 Di=9.2	Ob=32.7 Tra=27.6 Spi=13.3	NA	NA	I=8.4 II=18 III=73.6	EF=15.7 IN=1.4 CI=71.4 P=5.7 AMP=5.7	IF=11.4 NU=4.3 MU=11 OS=13	52.3 26.2 weeks
Ikem IC et al. 2006 [21] 73/100	n=89 64/36 32.7±17.1 RTA=60.7	Pr=18 Mi=32.6 Di=49.4	Co=40.4 Tra=25.8 Ob=24.7 Seg=3.4 Spi=5.6	NA	Mean=6h	I=24.7 II=36	EF=22.5 CI=77.5	IF=48.3 NU=7.8 MU=12.3 OS=12.3	31.5 17 weeks

Pr=proximal; MI=middle; Di=distal; Ep=epiphyse; Co=comminuted; Tra=transversal; Ob=oblique; Seg=segmental; Spi=spiral; EF=external fixator; IN=intramedullary nails; P=plate; AMP=amputation; IF=infection; NU=nonunion; MU=malunion; OS=osteomyelitis; NA=not applicable, CI=cast immobilization