







Original Article

Early and definitive treatment with ESIN, Kirschner wires, and external fixation in Gustilo and Anderson II–IIIC pediatric open fractures: A comparative study

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ABSTRACT

Objectives: Open fractures are still a significant cause of morbidity in pediatric patients. The objective of this study was to compare the safety of initial and definitive internal fixation treatment with elastic stable intramedullary nailing (ESIN), and Kirschner (K) wires, and external fixation in Type II and III Gustilo-Anderson pediatric open fractures.

Methods: This was an observational, retrospective, and cross-sectional study with a non-experimental design, where all the patients who were treated for Type II-IIIC open fractures, from January 2018 to August 2021, were included in the study.

Results: A total of 60 patients were included in the study, with a predominance of the male gender (61.7%, $n = 37$) and an average age of 8.7 years. Timing of surgery from the injury to surgical treatment was measured, with the most common interval being 12 h (13.33%, $n = 8$), internal fixation with K-wires was performed in 63.3% ($n = 38$) of the patients; and with ESIN in 30% ($n = 18$), with no complications, and in cases of external fixation 6.7% ($n = 4$) with soft-tissue infection seen in 3.33% ($n = 2$), associated with treatment with external fixation. Follow-up was done at 4, 6, and 12 months for the different procedures. The most frequently used antibiotics were clindamycin (35%) and cefazolin (21.67%).

Conclusion: The present study supports using ESIN and K-wires as early and definitive treatment in Gustilo-Anderson Type II-IIIC pediatric open fractures. External fixation is recommended only in cases where osteosynthesis with ESIN and K-wires is not an option.

Keywords: Elastic stable intramedullary nailing, Pediatric open fracture, Internal fixation, Osteosynthesis, TENS, K-wires, Gustilo-Anderson classification

INTRODUCTION

Trauma is the leading cause of death among children over 1 year of age and is a significant cause of permanent disability. The most frequent causes are falls, traffic accidents, and sports

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accidents.^[1] According to the World Health Organization, road traffic injuries are the leading cause of death among children and young people aged 5–29. Approximately 1.3 million lives are lost each year due to these injuries. In addition, between 20 and 50 million people suffer non-fatal injuries and many resulting in disabilities.^[2]

An open fracture is a fracture in which there is an open wound or break in the skin communicating with the site of the broken bone. They are generally caused by high-energy injuries and present with varying tissue and bone damage.^[3] It can be due to direct trauma, when a direct blow causes the fracture, and the energy is transmitted between the skin and soft-tissue or indirect trauma, where the application of force is away from the fracture site. The applied forces tend to twist or angle the bone.^[4]

The Gustilo-Anderson classification is the one most widely used and accepted in the medical literature for open fractures. This classification divides injuries into three types, considering the greater severity of the fracture and neurovascular involvement. Type III has three subtypes, Subtype A is characterized by a high-energy, contaminated, comminuted, and segmental fracture that has adequate soft-tissue coverage, which can be repaired primarily. Subtype B presents massive contamination with periosteal detachment and requires local reconstruction with flaps. Finally, Subtype C is an open fracture that presents vessel damage that requires repair, regardless of the size or contamination of the wound.^[8] It is summarized in [Table 1].

Table 1: Gustilo and Anderson classification.

Type	Description
Type I	Clean wound < 1 cm in diameter.
Type II	A laceration > 1 cm and < 10 cm without significant soft-tissue crushing.
Type III	An open segmental fracture or a single fracture with extensive soft-tissue injury > 10 cm. Type III is divided into three subtypes.
Type IIIA	Fracture despite high-energy trauma or extensive laceration or skin flaps
Type IIIB	Inadequate soft-tissue coverage with periosteal stripping.
Type IIIC	Any open fracture that is associated with a vascular injury that requires repair.

Table 2: Relationship between infection and fracture fixation.

	K-wires			ESIN			External fixation		
	Not used	Used	Total	Not used	Used	Total	Not used	Used	Total
Infection									
Absent	20	38	58	40	18	58	56	2	58
Present	2	0	2	2	0	2	0	2	2
Total	22	38	60	42	18	60	56	4	60

ESIN: Elastic stable intramedullary nailing

This study aimed to show if it is possible and with minimal complications to give early and definitive fixation with elastic stable intramedullary nailing (ESIN) and/or Kirschner (K) wires, of pediatric open fractures. Thus, avoiding major surgical procedures entail more significant risks to life and greater economic costs. The early definitive less invasive procedures would help the pediatric patients and their environment.

MATERIALS AND METHODS

This is an observational, retrospective, and cross-sectional study, with a non-experimental design, which included all of the patients treated for Type II and III open fractures in the traumatology and orthopedics department at Dr. Roberto Gilbert Elizalde Children’s Hospital in the period between January 2018 and August 2021. The medical records of patients who met the inclusion and exclusion criteria were reviewed and results were obtained through tabulation in an Excel spreadsheet.

The results were analyzed with the IBM SPSS Statistics 27.0 with a 95% confidence interval and a significance value $P < 0.05$.

Inclusion criteria

The following criteria were included in the study:

- Patients with a diagnosis of Type II-III Gustilo-Anderson open fractures
- Patients without the previous surgical intervention
- Patients treated surgically in the period between January 2018 and August 2021.

Exclusion criteria

The following criteria were excluded from the study:

- Patients with incomplete clinical files
- Patients improperly registered in the international code of diseases-10
- Patient with the previous musculoskeletal disorders
- Patients with the previous active infectious processes.

RESULTS

We analyzed 60 pediatric patients predominantly males, (61.7%, $n = 37$), while females were (38.3% $n = 23$). The

average age was 8.7 years (range 7–13). Regarding the time (hours) from the moment of injury to the surgical procedure, the mode was 12 h (13.33%, $n = 8$) followed by 8 h (10.00%, $n = 6$) and 4 h with 8.33% ($n = 5$). It should be noted that there was 1 case (1.7%) in which the time from the start of the injury to the surgical intervention was 504 h, due to the inappropriate referral of the patient to a specialized center.

Of the 60 patients studied, 23 had open fractures Type II, 17 had open fractures Type IIIA, 15 had Type IIIB, and five had Type IIIC. Four patients had open fractures of the humerus and 30 patients had open fractures of the forearm with involvement of one or both bones, with the radius being more common. In addition, nine patients suffered from open fractures of the femoral diaphysis, 13 patients had diaphyseal fractures of the tibia, and four patients had open foot fractures.

All patients were treated surgically, with osteosynthesis of the fracture. The most frequent fixation method was K-wires, in 63.3% ($n = 38$) of patients followed by ESIN in 30% ($n = 18$) and external fixation in the remaining 6.7% ($n = 4$). These were two patients with severe soft-tissue damage and unstable distal tibial open fractures and another two patients with a long time from injury to surgery (>24 h) [Table 2].

The most used antibiotics were clindamycin (35%) and cefazolin (21.67%). We had only 2 cases of infection (3.33%). One of these patients had a Type III C open fracture, with severe soft-tissue damage; the other patient had a 16 h delay before surgery was performed.

Follow-up was done for all patients, with a range of 4–12 months; with the most frequent period being 6 months (21.7%, $n = 13$), then 4 months (20.0%, $n = 12$), and finally 12 months (18.3%, $n = 11$), no complications other than two cases of infection were reported. Neither of these patients progressed to osteomyelitis and recovered satisfactorily until the end of the 12-month follow-up.

DISCUSSION

In a 5-year epidemiological, Reyes-Hernández *et al.*^[5] indicated that, out of the 52 patients in their study, the male gender predominated 3:1, with the average age of 6.9 years and 100% of open fractures required surgical treatment. Two parameters were concordant with our study, the gender and the time to surgical treatment.

Beraldo and Forlin had 126 patients with musculoskeletal firearm injuries (58 had fractures) in their study, with a mean age of 15 years and 5 months; 29.4% (63.8% of those with fractures) had orthopedic surgery, of which 39.1% had internal fixation; 21.8% had external fixation while the remaining 70.6% did not require orthopedic treatment.^[6] Therefore, there is no association with the data obtained in our study.

Arias-Ortiz *et al.* reported that external fixation had complications related to an infectious process in 28.6% followed by complications related to osteosynthesis in 23.8%.^[7] However, we found a much lower frequency of infection associated with external fixation (3.33% $n = 2$), despite the fact that they were five patients with Type IIIC open fractures in our sample.

A recent publication by Moyolema reported a child with a Type IIIC open fracture of the proximal humerus, with more than 12 h delay between the trauma and its initial orthopedic treatment with ESIN. The patient had good functional outcome without complications or infection.^[9] Heo *et al.* concluded in their study of 16 patients (13 were open fractures) with diaphyseal tibial fractures that even with open fractures or soft-tissue injuries, elastic nailing could achieve satisfactory results in young children, with minimal complications of delayed bone healing or infection, which is consistent with the results of our study.^[10] Similarly, Pandya and Edmonds had previously shown that immediate, flexible nailing of open pediatric tibial shaft fractures could be performed safely, with minimal risk of injury or infectious complications.^[11] Clinicians should understand that prolonged bone healing (particularly in Type II or III injuries) should be expected in patients who undergo immediate and flexible nailing of their open fractures. These results are consistent with those of our study.

A limitation of our study is not having data on the antibiotic initiation interval in the patients under study. However, antibiotics are usually started in our hospital as soon as the patient arrives at the emergency room. In this context, the most used antibiotics were clindamycin (35%) and cefazolin (21.67%), resulting in only 2 cases of infection (3.33%). Another limitation is the fact that there were a small number of patients in each subtype of fractures that did not allow for comparisons between the subtypes.

CONCLUSION

Based on the present study, using internal fixation with K-wires and ESIN is recommended as a safe option for immediate definitive treatment in Type II and III Gustilo-Anderson pediatric open fractures. In addition, these fixation methods minimize surgical injury to the soft tissues and minimize the risks involved in major surgical procedures.

RECOMMENDATIONS

The Gustilo-Anderson classification is currently widely used to classify open fractures and is most useful in adult patients. However, due to the paucity of pediatric population clinical studies, its application and usefulness in the pediatric community remain controversial. Based on more studies such as the current one, guidelines for the management of pediatric open fractures could be developed. Although our

sample size was comparatively large, a larger number of cases would allow for more significant recommendations.

AUTHORS' CONTRIBUTIONS

CJ: Concepts, desing, definition of intellectual content, data acquisition, data analysis, statistical analysis JQ: Concepts, manuscript editing and review PJ: Concepts, desing, manuscript editing and review, AG: Manuscript preparation JAM: Data acquisition RDD: Data analysis. All authors have critically reviewed and approved the final draft and are responsible for the manuscript's content and similarity index.

ETHICAL APPROVAL

This study was approved by the research committee of the Children's Hospital Dr. Roberto Gilbert E. Guayaquil - Ecuador, February 22, 2022, with approval number HRG-DDI-OFC-020.

DECLARATION OF PATIENT CONSENT

The authors certify that they have obtained all appropriate patients consent forms. In the form, the patients have given their consent for their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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CONFLICTS OF INTEREST

There are no conflicting relationships or activities.

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