Paediatric type I open tibia fractures: are antibiotics alone sufficient?

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Cite this article:
Bone Jt Open 2025;6(8):
905–914.

DOI: 10.1302/2633-1462.
68.BJO-2025-0060.R1

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Aims

The conventional management of the soft-tissue component of an open fracture involves emergent debridement. There is, however, evidence that questions this approach in the management of Gustilo-Anderson type I open fractures in paediatric patients. This systematic review aims to explore differences in infection rates between nonoperative management with antibiotics and operative debridement in children with type I open lower limb tibial fractures that do not require surgical fixation.

Methods

A systematic review following the PRISMA guidelines was conducted. Patients aged under 18 years with Gustilo-Anderson type I open tibia fractures treated with either antibiotics alone or operative debridement were included. Polytrauma patients and those requiring operative fracture stabilization were excluded. Study bias was assessed with the ROBINS-I (Risk of Bias in Non-randomized Studies of Interventions) tool.

Results

Ten retrospective studies of 123 patients with Gustilo-Anderson type I open tibial fractures were included. Nonoperative management in the emergency department with antibiotics was used in 41 patients, with two infections reported (4.87%). Operative debridement was performed in 82 patients, with two infections reported (2.33%).

Conclusion

The optimum management for paediatric Gustilo-Anderson type I open tibia fractures remains unclear. There may be selected cases, with true low-energy injury without operative fixation requirements, which can be managed in the emergency department. However, there is not sufficient high-quality evidence to advocate for regular deviation from current guidelines in open tibia fractures in paediatric patients. Decision-making must take into account the energy absorbed, as this factor can be misleading within the current classification system.

Take home message

- The optimum management strategy for Gustilo-Anderson type I open tibia fractures in children is unclear.
- True low-energy injuries without operative fixation requirements can be managed in the emergency department.

Introduction

Open fractures are significant injuries that are associated with increased morbidity and mortality compared to closed fractures.[1] Although they constitute a small proportion of paediatric fractures, their management requires careful consideration.[2] The Gustilo-Anderson (GA)[3] classification system is widely used to categorize these injuries based on wound size and the extent of soft-tissue damage, with type I fractures characterized by clean wounds less than 1 cm in size.

Standard treatment protocols advocate prompt washout, surgical debridement, and

Table I. Electronic database search strategy.

	Concept 1 (participants)	AND	Concept 2 (intervention)	AND/OR	Concept 3 (comparator)	AND	Concept 4 (outcome)
MeSH terms							
OR	Paediatric		Washout		Antibiotics		Infection
OR	Child		Debridement				Osteomyelitis
OR	Pediatric						
OR	Adolescent						
OR	Fractures, lower limb						
AND	Open fracture						
OR	Gustilo Anderson						
Key words							
OR	Paediatric femoral fracture		Operative		Emergency department		Surgical wound infection
	Open fracture children		washout and debridement		Non operative		Union
	Lower Extremity		Theatre				Delayed union
	Femur						Malunion
	Knee						Reoperation
	Tibia						
	Fibula						
	Ankle						
	Metatarsal						
	Tarsal						

fracture stabilization. Early antibiotic administration has an additional role in reducing infection rates in all age groups irrespective of fracture location,[4] and these recommendations align with national guidelines, including the British Orthopaedic Association Standards for Trauma (BOAST-4).[5]

There is, however, emerging evidence to suggest that the healing characteristics of open fractures of the immature skeleton are distinct from adult fractures, often with more favourable outcomes.[6-10] Lower infection rates in children have been attributed to unique physiological factors, including a thicker and more vascularized periosteum, which enhances bone healing.[11-14]

The management of GA type I fractures, particularly the necessity for operative debridement, remains a subject of ongoing debate. Recent retrospective studies, primarily focused on upper limb fractures, suggest that paediatric patients who do not require operative fixation may be safely managed with antibiotics alone, without compromising clinical outcomes.[6-10]

Despite these findings, there remains a paucity of comparative research across different age groups and anatomical locations, particularly concerning lower limb fractures. The optimal management strategy for paediatric open lower limb fractures that do not require surgical stabilization remains unclear. This study aims to critically assess the current evidence comparing nonoperative management (antibiotics alone) with operative intervention (surgical washout, debridement, and antibiotics) to guide future clinical practice.

Methods

This review was performed using methodology outlined in the Cochrane Handbook of Systematic Review of Interventions.[15] It is reported in accordance with the PRISMA statement.[16] An a priori protocol was registered prospectively on the PROSPERO international register of systematic reviews (registration number: CRD42025639075).[17]

The literature search was conducted independently by two authors (RFLH, NM) in MEDLINE, Embase, and Web of Science (WoS) from inception until November 2024 using MeSH terms and free-text strategies (Table I). No language limits were applied. The reference lists of included articles were hand-searched for relevant publications, and grey literature was searched via Google Scholar.

Studies reporting adverse outcomes in patients < 18 years with GA type I open tibial fractures, managed with antibiotics with or without emergency department debridement, formal operative debridement, or both were included. Adults (> 18 years), polytrauma, open joint injuries, upper limb fractures, femoral fractures, closed fractures, and fractures where external, intra-, or extramedullary operative stabilization was required were excluded (Figure 1).

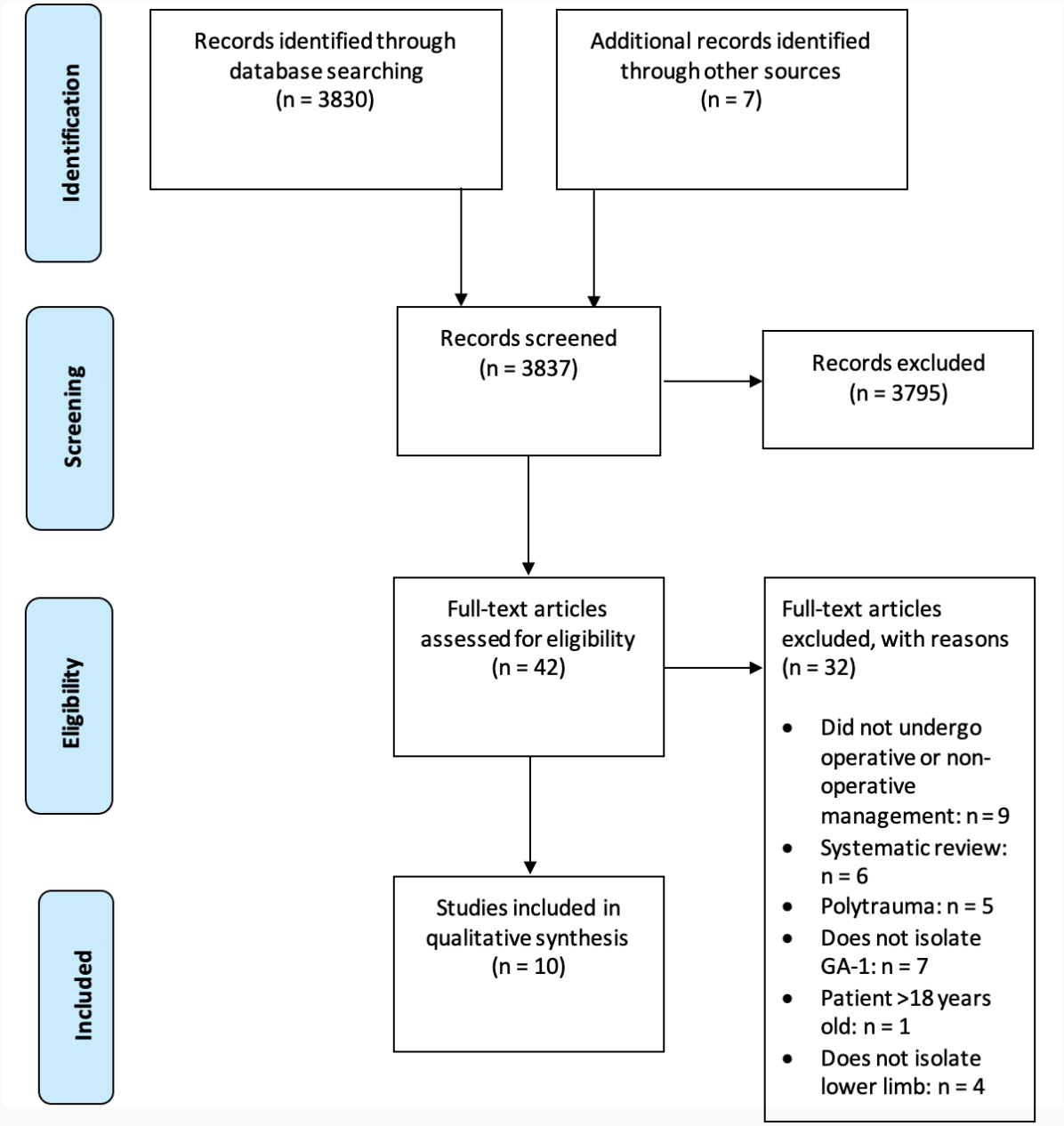

Fig. 1
PRISMA flow diagram. GA-1, Gustilo-Anderson type I.

Study bias was assessed with the ROBINS-I (Risk of Bias in Non-randomized Studies of Interventions) tool (Figures 2 and 3).[17]

The primary outcome was the rate of infection (superficial soft-tissue infection and/or osteomyelitis (OM)). Secondary outcomes were unplanned reoperation, time to union (clinical and/or radiological; weeks), union abnormalities (delayed union, malunion, nonunion, or refracture), and complications.

Information recorded included publication date, author, country of origin, level of evidence, sex, mean age and range, total number of fractures, fracture location, and follow-up. Additional information included use of oral/intravenous (IV) antibiotics, time from injury to first dose of antibiotic, and duration of treatment.

Statistical analysis

Descriptive analyses were performed for patient demographics, treatments, and outcome data.

Results

The search strategy identified 3,837 articles, of which ten retrospective cohort studies reporting 123 GA type I open tibial fractures were identified (Table II).[6,7,12,18–26]

Studies were from the USA (8) and UK (2). The mean age was 7.0 years (2 to 17.5) across all studies (Table II and Table III). Sex distribution was limited to four studies.

Studies were assessed by the ROBINS-I tool for non-randomized studies of intervention, and all showed moderate to serious risk of bias because of their retrospective nature, lack of pre-published protocols, confounding variables between treatment groups, attrition, and reporting bias.

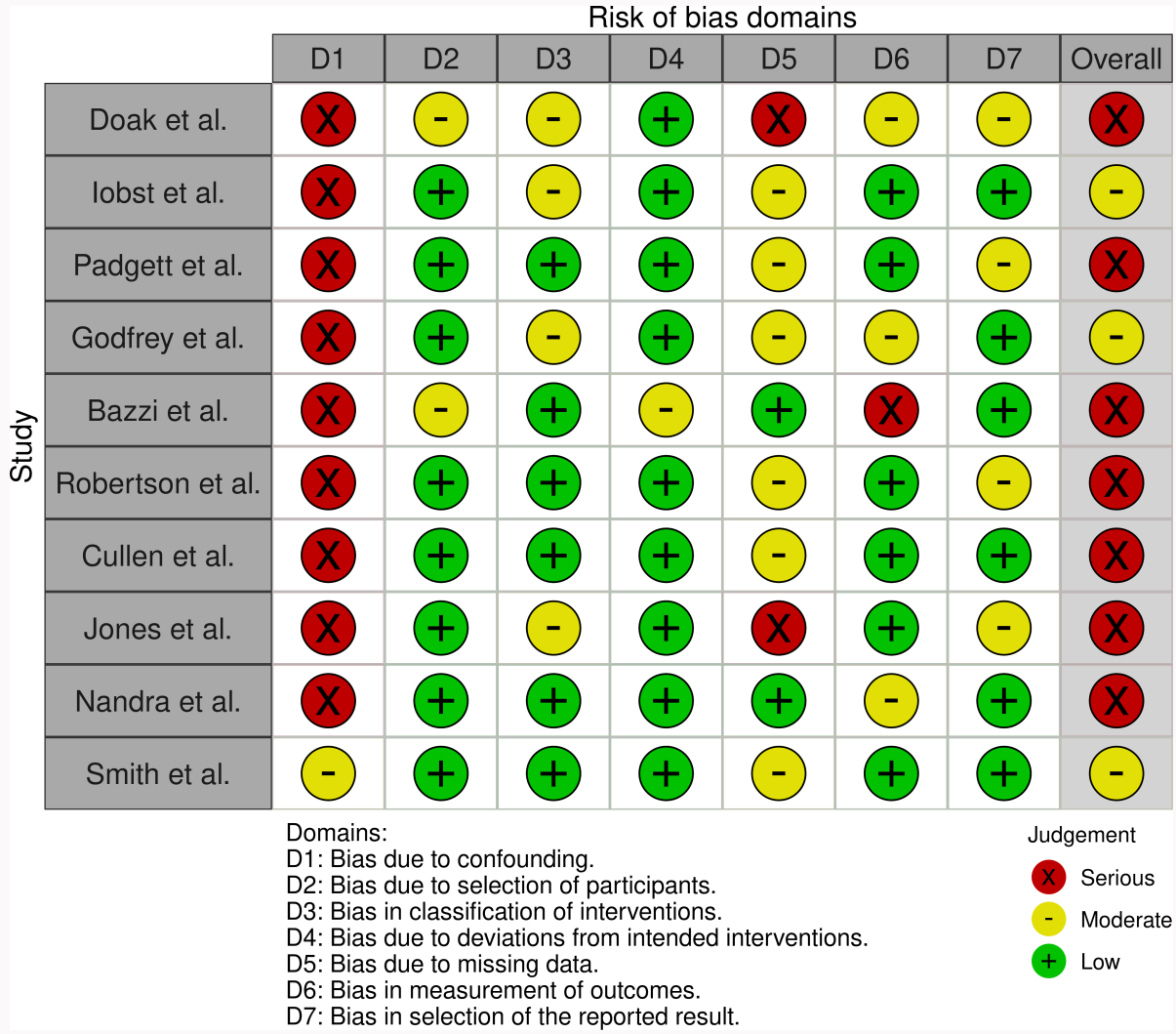

Fig. 2
ROBINS-I (Risk of Bias in Non-randomized Studies of Interventions) risk of bias traffic light.

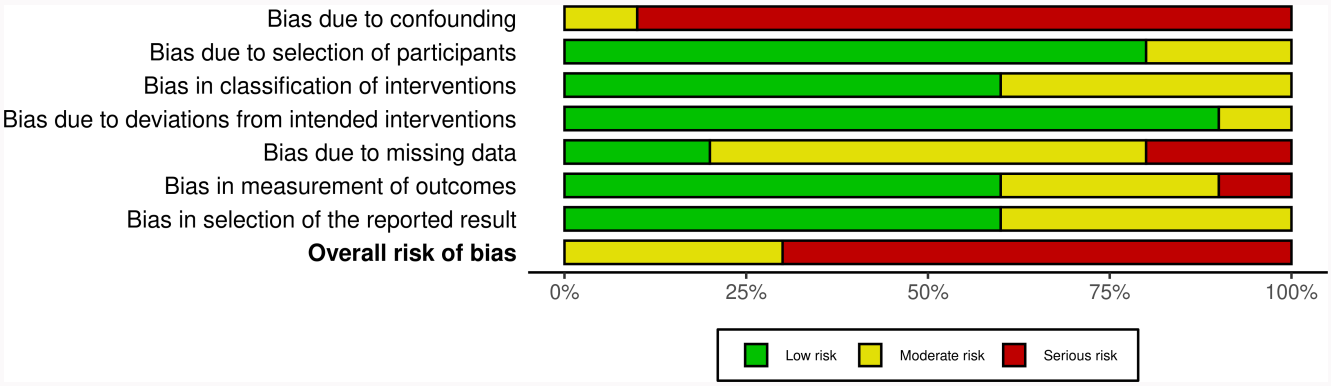

Fig. 3
ROBINS-I (Risk of Bias in Non-randomized Studies of Interventions) risk of bias summary.

The primary outcome of infection was reported in all studies. Infection was reported in two patients (n = 2/82; 2.44%) managed with formal operative debridement, and two patients (n = 2/41; 4.87%) managed nonoperatively (p = 0.600) (Table IV).

In the operative group, both operative infections were superficial, involving *Pseudomonas aeruginosa*, and were reported in the same study.[25] The age of children was not reported, and both were treated with oral antibiotics, with no record of the type or duration, which led to a full recovery in both patients. The nonoperatively managed patient group

Table II. Study characteristics.

Author	Title	Year	Location	Methods	Mean age, yrs (range)	Total number of patients with Grade 1 open fracture (location)	Total number of males	Total number of females
Doak and Ferrick[6]	Nonoperative management of paediatric grade 1 open fractures with less than a 24-hour admission	2009	USA	Retrospective cohort study	(2 to 15)	n = 5 (tibia)	N/A	N/A
Iobst et al[7]	Nonoperative management of paediatric type 1 open fractures	2005	USA	Retrospective cohort study	10 (4 to 15)	n = 8 (tibia)	N/A	N/A
Padgett et al[23]	Comparison of nonoperative vs operative management in paediatric Gustilo–Anderson type I open tibia fractures	2022	USA	Retrospective cohort study	7.64 (SD 3.67)	n = 12 (tibia)	11	1
Godfrey et al[22]	Management of paediatric type I open fractures in the emergency department or operating room: a multicentre perspective	2019	USA	Retrospective cohort study	8.5 (2 to 18)	n = 2 (tibia)	N/A	N/A
Bazzi et al[24]	Is nonoperative treatment of paediatric type I open fractures safe and effective?	2014	USA	Retrospective cohort study	8.6 (4 to 16)	n = 14 (tibia)	N/A	N/A
Robertson et al[20]	Open fractures of the tibia and femur in children	1996	USA	Retrospective cohort study	7.5 (5 to 10)	n = 4 (tibia)	2	2
Cullen et al[19]	Open fracture of the tibia in children	1996	USA	Retrospective cohort study	9 (3 to 17)	n = 12 (tibia)	N/A	N/A
Jones and Duncan[25]	Open tibial fractures in children under 13 years of age--10 years' experience	2003	UK	Retrospective cohort study	7.4	n = 38 (tibia)	N/A	N/A
Nandra et al[26]	The management of open tibial fractures in children	2017	UK	Retrospective cohort study	7 (2 to 14)	n = 6 (tibia)	N/A	N/A
Smith et al[12]	Orthoplastic management of open tibial fractures in children: a consecutive five-year series from a paediatric major trauma centre	2021	USA	Retrospective cohort study	7.8 (SD 2.7)	n = 2 (tibia)	N/A	N/A

N/A, not available.

recorded one superficial and one deep infection. One superficial infection occurred in a five-year-old male, who presented six days after injury with erythema and a serosanguinous wound discharge. He was admitted for presumed infection and received two days of intravenous (IV) clindamycin as he was allergic to penicillin, which led to a full recovery. The causative organism was not identified, and he was discharged with a two-week course of oral clindamycin. The fracture united in 11 weeks without further complications.

One deep infection occurred in a 15-year-old male, three months after a comminuted, mid-shaft tibia fracture after a fall down stairs.Clinically, the fracture had healed, but a small nidus of dead bone was found anterior to the fracture site, which led to a draining sinus over the anterior tibia. He underwent operative debridement of dead bone, excision of sinus, and went on to make an uncomplicated recovery. This is the only reoperation reported in the nonoperatively managed group. This case was categorized as a type I open fracture, even though it is described as a comminuted

Table III. Table of interventions.

Author	Intervention (operative, nonoperative, or both)	If operative, was there plastic surgery involvement?	If nonoperative, was emergency room debridement performed?	Intravenous or oral antibiotics or both	Mean time from injury to antibiotic (range)	Length of antibiotic course, days (range)	Follow-up period (range)
Doak and Ferrick[6]	Nonoperative	-	Yes	Both	N/A	1 to 7	Until fracture union
Iobst et al[7]	Nonoperative	-	Yes	Both	4 hrs 42 mins	2 to 7	Until fracture union
Padgett et al[23]	Both	No	Yes	Both	1 hr 47 mins (SD 1 hr 24 mins) (nonoperative) 1 hr 18 mins (SD 48 mins) (operative)	1 to 2	3 mths 21 days (SD 2 mths) (nonoperative)
Godfrey et al[22]	Both	No	Yes	Both	N/A	1	Until fracture union
Bazzi et al[24]	Nonoperative	-	Yes	Both	N/A	3 to 14	4 mths 6 days (SD 8 mths)
Robertson et al[20]	Operative	No	-	Intravenous	N/A	N/A	N/A
Cullen et al[19]	Operative	Yes	-	Intravenous	N/A	2	14 mths (2 to 75 mths)
Jones and Duncan[25]	Operative	No	-	Intravenous	N/A	1 to 15	N/A
Nandra et al [26]	Operative	No	-	Intravenous	3 hrs	2 to 4	6 mths 26 days (2 mths 24 days to 13 mths 3 days)
Smith et al[12]	Operative	Yes	-	Intravenous	2 hrs 16 mins	N/A	24 mths

- , not applicable; N/A, not available.

Table IV. Infection rates.

		Rates of infection (n, %)	
Author	Study total (operative vs nonoperative)	Operative	Nonoperative
Doak and Ferrick[6]	5 (- vs 5)	-	1 (2.43)
Iobst et al[7]	8 (- vs 8)	-	1 (2.43)
Padgett et al[23]	17 (5 vs 12)	0 (0)	0 (0)
Godfrey et al[22]	17 (15 vs 2)	0 (0)	0 (0)
Bazzi et al[24]	14 (- vs 14)	-	0 (0)
Robertson et al[20]	4 (4 vs -)	0 (0)	-
Cullen et al[19]	12 (12 vs -)	0 (0)	-
Jones and Duncan[25]	38 (38 vs -)	2 (2.33)	-
Nandra et al [26]	6 (6 vs -)	0 (0)	-
Smith et al[12]	2 (2 vs -)	0 (0)	-
Total	123 (82 vs 41)	2 (2.44)	2 (4.87)

-, not applicable.

fracture—a detail that would typically suggest a high-energy mechanism and therefore more significant soft-tissue injury than suggested by the size of the wound.

Nonunion and malunion were reported in all studies involving nonoperative management and eight involving operative management (Table V). One nonunion (n = 1/41;

Table V. Secondary outcomes.

Author	Study total (operative vs nonoperative)	Nonunion		Malunion		Time to union, wks		Return to theatres	
		Operative	Nonoperative	Operative	Nonoperative	Operative	Nonoperative	Operative	Nonoperative
Doak and Ferrick[6]	5 (- vs 5)	-	0	-	0	-	9.52	-	0
Iobst et al[7]	8 (- vs 8)	-	0	-	0	-	6.85	-	1
Padgett et al[23]	17 (5 vs 12	Not extractable	1	Not extractable	1	N/A	N/A	0	0
Godfrey et al[22]	17 (15 vs 2)	0	0	0	0	N/A	N/A	0	0
Bazzi et al[24]	14 (- vs 14)	-	0	-	0	-	11.71 (8.57 to 17.14)	-	0
Robertson et al[20]	4 (4 vs -)	0	-	3	-	9 (7 to 10)	-	0	-
Cullen et al[19]	12 (12 vs -)	0	-	0	-	12	-	0	-
Jones and Duncan[25]*	38 (38 vs -)	0	-	5	-	10.44	-	0	-
Nandra et al [26]	6 (6 vs -)	0	-	0	-	7.14 (5.4 to 14)	-	0	-
Smith et al[12]	2 (2 vs -)	0	-	0	-	N/A	-	0	-
Total						9.65	9.36	0 (0%)	1 (2.43%)

*Additional complications: one fasciotomy, one extensor hallucis longus tethering, one delayed union.
-, not applicable; N/A, not available.

Table VI. Definitions.

Author	Definitions		
	Nonunion	Delayed union	Malunion
Doak and Ferrick[6]	N/A	> 16 weeks	N/A
Iobst et al[7]	N/A	Incomplete healing of closed tibia fracture at 16 weeks	N/A
Padgett et al[23]	No radiological callus at 6 months	> 16 weeks	> 10° sagittal or > 5° coronal angulation
Godfrey et al[22]	N/A	N/A	N/A
Bazzi et al[24]	N/A	N/A	N/A
Robertson et al[20]	Absence or arrest of fracture healing on serial roentgenograms	> 24 weeks	N/A
Cullen et al[19]	Absence of arrest of fracture healing after 6 months immobilization	> 16 weeks	> 10° angulation in any plane
Jones and Duncan[25]	N/A	N/A	> 10° sagittal or > 5° coronal angulation
Nandra et al [26]	N/A	N/A	N/A
Smith et al[12]	N/A	N/A	N/A

N/A, not available.

2.43%) and one malunion (n = 1/41; 2.43%) were reported in the nonoperative group.[23] The nonunion was identified in a 13-year-old female, was treated with bone stimulation, and had healed at 39-week follow-up but refractured at 13 months. A 6° valgus deformity was identified in a five-year-

Table VII. Intra-study definitions of primary outcomes (soft-tissue infections (I), deep infection/osteomyelitis (DI/OM)) and secondary outcomes (nonunion (NU), malunion (MU), delayed union (DU)).

Study	Author	Date	Intra-study definitions
1	Doak and Ferrick[6]	2009	Primary: (I) defined as fever, persistent or purulent drainage from their wound, or erythema and swelling that was more significant than would be expected from the fracture alone, (DI/OM) not defined, not used. Secondary: (NU) not defined, (DU) defined as union at > 16 weeks, (MU) not defined.
2	Iobst et al[7]	2005	Primary: (I) defined as inflammation of the skin and subcutaneous tissues with local drainage and the absence of radiological evidence of osteomyelitis, (DI/OM) defined as increasing pain drainage from the wound and radiological changes within the bone, with all such patients proceeding to operative debridement. Secondary: (NU) not defined, (DU) defined as incomplete healing of closed tibia fracture at 16 weeks, (MU) not defined
3	Padgett et al[23]	2022	Primary: (I) not defined but used as diagnosis, (OM) not defined but used as diagnosis. Secondary: (NU) defined as no radiological callus at 6 months, (DU) defined as union at > 16 weeks, (MU) defined as > 10 d sagittal or > 5 d coronal angulation
4	Godfrey et al[22]	2019	Primary: (I) defined as superficial infection, (DI/OM) defined as infection. Secondary: (NU)/(MU)/(DU) not defined.
5	Bazzi et al[24]	2014	Primary: (I) not defined but used as diagnosis, (OM) not defined but used as diagnosis. Secondary: (NU) defined as absence of osseous union after more than 6 months after the injury, (MU) term used but not defined
6	Robertson et al[20]	1996	Primary: (I) defined as infection involving skin and subcutaneous tissue, (DI/OM) defined as clinical or radiological evidence of bony infection or positive bone cultures for bacterial growth. Secondary: (NU) arrest of healing on serial radiographs, (MU) not reported, (DU) union occurring at > 24 weeks after the injury
7	Cullen et al[19]	1996	Primary: (I) not defined, used as diagnosis, (DI/OM) not defined, used as diagnosis. Secondary: (MU) residual angulation > 10° in any plane), (NU) not reported, (DU) in complete healing at 16 weeks
8	Jones and Duncan[25]	2003	Primary: (I) not defined but used as diagnosis, (OM) not defined but used as diagnosis. Secondary: (NU)/(DU) not defined but used as diagnosis, (MU) not defined
9	Nandra et al [26]	2017	Primary: (I) superficial infection, (DI/OM) deed infection diagnosed on basis of positive culture from revision surgery. Secondary: (MU)/(NU)/(DU) not defined but used as diagnosis
10	Smith et al[12]	2021	Primary: (I) superficial infection, (DI/OM) made according to criteria as established by the USA Centers for Disease Control and Prevention. Secondary: (NU)/(DU)/(MU) not defined but used as diagnosis

DI, deep infection; DU, delayed union; I, soft-tissue infections; MU, malunion; NU, nonunion; OM, osteomyelitis.

old, 11 weeks following injury, but did not require operative correction.

Malunion (seven angular, one rotational) was identified in eight patients (n = 8/77; 10.39%) in the operatively managed group. None required corrective surgery or had significant leg length discrepancy. Additional complications in the operative group included delayed union (1), compartment syndrome requiring fasciotomy (1), and extensor hallucis longus tethering (1).

Discussion

The current consensus on open paediatric fracture management emphasizes early administration of antibiotics, wound exploration, debridement, and fracture fixation where necessary, aligning with accepted adult protocols. This study represents the first systematic review comparing nonoperative management with surgical debridement for GA type I open tibia fractures in children.

This study reported a higher infection rate (4.87%; n = 2/41) in fractures managed nonoperatively,[27] compared to an equivalent review of GA type I upper limb fractures, aligning with adult studies that demonstrate an increased infection risk in lower limb fractures.[28,29]

A survey by the Paediatric Orthopedic Society of North America (POSNA) identified that 19% to 31% of respondents supported superficial incision, drainage, and antibiotics in the emergency department.[30] Of note, all included studies reported on populations in North America and the UK, reflecting the growing debate in the management of these injuries in these regions.

While there are potential advantages associated with nonoperative treatment, including the elimination of risks associated with surgery and general anaesthesia,[31] reducing

operating theatre costs, and minimizing the psychological burden of surgery on both the child and their parents,[32] the single case of deep infection is of concern and warrants careful scrutiny.

This involved a 15-year-old with a comminuted tibial shaft fracture after a fall down stairs. The fracture pattern suggests a high-energy injury mechanism and therefore is likely to have resulted extensive soft-tissue disruption that may have been underestimated at initial assessment, something which was not highlighted in this study. For this reason, the infection rate may be overstated in this study.

This case also highlights the effect of patient age, as previous studies indicate children aged over 12 years may have worse infection outcomes; this should also be a factor in the decision to manage the soft-tissue component of this injury.[27,33]

This review highlights two important considerations: firstly, the application and limitations of the GA classification, and secondly, the importance of methodical injury assessment in the emergency department if nonoperative measures are to be considered. The GA classification is known to have limited interobserver reliability, reported at 60% and a kappa value of 0.53 in previous studies.[34,35] Additionally, the external appearance of an injury does not always correspond to the extent of soft-tissue damage. The GA classification does not account for tissue viability or progressive necrosis, which can develop over time in more severe injuries. Although the GA classification was designed as a tool to be applied after intraoperative irrigation and debridement of a fracture was complete, an initial classification is commonly given to injuries on first presentation to the emergency department. It has been shown that up to 12% of all injuries may be initially misclassified, particularly in fractures with bone loss at presentation.[36] There is therefore a real danger of confirmation bias, with clinicians under-classifying the soft-tissue injury.[37]

Factors such as the degree of soft-tissue damage and periosteal stripping that are noticed following wound debridement and the mechanism of injury are far more significant than the wound size.

A newer preoperative classification proposal for paediatric open fractures highlights the extent of soft-tissue injury, skeletal stability, and mechanism as important factors.[38] Clinicians should suspect the injury is more severe than initially anticipated unless specific indicators of lower energy exist. A methodical assessment of the wound, associated bruising, fracture displacement, and comminution in addition to a high-velocity mechanism all suggest higher energy transfer. For this reason, the authors of this review suggest the default should be to continue with operative debridement and classification unless a clear low-energy injury is evident.

There are important limitations associated with the methodology of the available studies, including the level of evidence, the lack of consistent recording and age stratification, and the small number of cases. Additionally, there are inconsistencies in defining secondary outcomes such as nonunion, malunion, and delayed union. Malunion criteria varied by fracture site, and nonunion definitions ranged from lack of healing at six months to absence of progression on serial radiographs (Tables VI and VII). While it was not possible to make robust conclusions due to low reporting rates, the overall angular malunion rate of 7.0% aligns with previously reported studies.[39]

The optimum management strategy for GA type I open tibia fractures in children remains unclear. The findings do not support a change in current practice, but suggest that deviation from accepted national guidelines may be appropriate in carefully selected cases. Management decisions should consider patient age, injury mechanism, careful soft-tissue assessment, and associated injuries. Further high-quality research is required to refine patient selection criteria and establish clearer treatment recommendation.

In conclusion, the optimum management for paediatric GA type I open tibia fractures remains unclear. There may be selected cases, with true low-energy injuries and without operative fixation requirements, which can be managed in the emergency department. However, there is insufficient high-quality evidence to advocate for regular deviation from current guidelines in open tibia fractures in paediatric patients.

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Funding statement

The author(s) received no financial or material support for the research, authorship, and/or publication of this article.

ICMJE COI statement

Y. Gelfer is a member of the editorial board of The Bone & Joint Journal and the associate editor of EFORT Open Review. F. Monsell is Vice President of the British Orthopaedic Association.

Data sharing

All data generated or analyzed during this study are included in the published article and/or in the supplementary material.

Open access funding

The open access fee for this article was self-funded.