Clinical/Basic Science Research Article

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Open tibial shaft fractures: treatment patterns in sub-Saharan Africa

ORCA Study Group

Abstract

Objective: Open tibial shaft fractures are a leading cause of disability worldwide, particularly in low and middle-income countries (LMICs). Guidelines for these injuries have been developed in many high-income countries, but treatment patterns across Africa are less well-documented.

Methods: A survey was distributed to orthopaedic service providers across sub-Saharan Africa. Information gathered included surgeon and practice setting demographics and treatment preferences for open tibial shaft fractures across 3 domains: initial debridement, antibiotic administration, and fracture stabilization. Responses were grouped according to country income level and were compared between LMICs and upper middle-income countries (UMICs).

Results: Responses from 261 survey participants from 31 countries were analyzed, with 80% of respondents practicing in LMICs. Most respondents were male practicing orthopaedic surgeons at a tertiary referral hospital. For all respondents, initial debridement occurred most frequently in the operating room (OR) within the first 24 hours, but LMIC surgeons more frequently reported delays due to equipment availability, treatment cost, and OR availability. Compared with their UMIC counterparts, LMIC surgeons less frequently confirmed tetanus vaccination status and more frequently used extended courses of postoperative antibiotics. LMIC surgeons reported lower rates of using internal fixation, particularly for high-grade and late-presenting fractures.

Conclusions: This study describes management characteristics of open tibial shaft fractures in sub-Saharan Africa. Notably, there were reported differences in wound management, antibiotic administration, and fracture stabilization between LMICs and UMICs. These findings suggest opportunities for standardization where evidence is available and further research where it is lacking.

Level of Evidence: VI—Cross-Sectional Study.

Key Words: sub-Saharan Africa, tibial fractures; debridement, antibiotic prophylaxis, fracture fixation, practice patterns, low-resource setting

1. Introduction

Tibial shaft fractures are a leading cause of disability worldwide.[1] Because many of these fractures present as open injuries, they are strongly associated with costly complications including osteomyelitis, nonunion, and amputation.[2,3] The burden of these injuries is especially pronounced in low-income countries (LICs) and low- and middle-income countries (LMICs), where incidence is rising because of increases in road traffic accidents.[1,4,5]

Successful management of open tibial shaft fractures often requires initial management decisions that can have a substantial impact on patients' short-term and long-term prognosis. Gold standard guidelines for these injuries have been developed in high-income countries (HICs) and include prompt debridement, prophylactic antibiotics, and early soft-tissue coverage.[2,6–9] However, the management of these fractures in other settings, particularly LICs and LMICs in Africa, varies based on numerous factors, including fracture type, surgeon training, resource limitations, treatment setting, and availability of financial mechanisms such as insurance to provide care for patients without ability to pay.[10,11]

Compared with other practice settings, nationally recognized best practices and treatment patterns for open tibial shaft fractures across Africa are less well-documented,[5,11,12] and these injuries may be managed by a wider spectrum of providers,[13,14] including general surgeons, paramedical orthopaedic clinical officers, and traditional bonesetters. Identifying discrepancies in treatment patterns and the barriers to care that lead to them will inform future decisions about resource allocation that can best improve the treatment of these injuries in African countries. Therefore, this study aims to assess the treatment of open tibial shaft fractures in sub-Saharan African countries.

2. Methods

2.1. Survey Design and Distribution

This study was deemed exempt from institutional review board approval. We distributed a cross-sectional survey among healthcare

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providers who surgically treat patients with open tibial shaft fractures practicing in sub-Saharan Africa and used a convenience sampling method of members from the College of Surgeons and Central and Southern Africa (COSECSA), an academic surgical consortium that has trained over 700 surgeons in East, Central, and Southern Africa,[15] and OTA/AO Alliance, a developmental nonprofit orthopaedic organization. To increase participation, we also used a snowball sampling method of sub-Saharan surgeons who are not part of COSECSA, asking identified surgeons to refer us to additional surgeons in their professional networks who may be appropriate survey respondents.

The survey assessed surgeons' treatment decisions for open tibial shaft fractures, based on both individual preference and perception of institutional capability. Survey questions were developed based on existing literature on open tibial fracture management and a similar survey conducted among Latin American providers[12] (see Appendix, Supplemental Digital Content 1, http://links.lww.com/OTAI/A72). The survey was reviewed and edited based on feedback from orthopaedic surgeons in Tanzania, Malawi, South Africa, the United Kingdom, and the United States who participate in the Orthopaedic Research Collaboration for Africa (ORCA). The English survey was translated into French by a bilingual orthopaedic surgeon (R.G.). The French version underwent reverse translation back to English, which was subsequently distributed to the authorship group for final review.

The survey collected demographic information about the treating surgeon and their practice, including sex, country of employment, type of surgical training (orthopaedic vs. general surgery), level of training (attending or resident), years of practice, practice setting (academic, private, governmental, or mission), and hospital level (district, regional, or referral). Open tibial fracture treatment was categorized into 2 groups based on the Gustilo-Anderson (GA) classification[16]: The first group included type I and type II fractures (GA-I/II) and the second group included type III fractures (GA-III). The survey queried responses related to 3 treatment domains: initial irrigation and debridement, antibiotic prophylaxis, and fracture stabilization (see Appendix, Supplemental Digital Content 1, http://links.lww.com/OTAI/A72). Responses were collected using Research Electronic Data Capture (REDCap)[17] or Google Forms[18,19] in areas where REDCap was not accessible.

2.2. Statistical Methods

Summary statistics were calculated, and responses were categorized according to World Bank income data as either an LIC/LMIC or a UMIC (upper middle-income country). Of note, no country in the survey was classified as an HIC. In an exploratory analysis, we examined responses according to the resource level of the hospital in which the surgeon practices, categorized into groups of district hospital compared with regional or referral hospital. Comparisons among groups were performed using the Pearson chi-square test with $\alpha = 0.05$ defined as the significance level. All analyses were performed using STATA SE version 16 (StataCorp).

3. Results

3.1. Participant Demographics

There were 261 survey participants from 31 countries (16 LICs, 12 LMICs, and 3 UMICs), with 37% from LICs, 43% from LMICs, and 20% from UMICs. Most respondents were male (86.6%), were practicing orthopaedic surgeons (62.8%), and were in their first decade of practice (75%). Approximately two-thirds of respondents worked at a tertiary referral hospital (Table 1). A list of countries represented in the survey is given in Table 2.

TABLE 1

Characteristics of Respondents

Characteristic	Total (n = 261)
Male sex	226 (86.6%)
Surgical residency	
Completed residency in orthopaedic surgery	164 (62.8%)
Completed residency in general surgery or other surgical specialty	12 (4.6%)
No surgical residency (N = 85)	
Clinical officer or nonphysician clinician	33 (38.8%)
Current surgical trainee	29 (34.1%)
Other physician	5 (5.9%)
Other	18 (21.1%)
Years of practice after surgical training (N = 176)	
0–5 y	89 (50.6%)
5–10 y	43 (24.4%)
10–20 y	33 (18.8%)
≥20 y	11 (6.2%)
Practice setting	
Academic	110 (42.1%)
Private hospital	60 (23%)
Government hospital	153 (58.6%)
Mission hospital	22 (8.4%)
Other	5 (1.9%)
Hospital level (N = 253)	
First level (district)	42 (16.6%)
Second level (regional)	47 (18.6%)
Third level (referral)	164 (64.8%)

3.2. Domain 1: Irrigation and Debridement

Most participants from both LIC/LMICs (94.4%) and UMICs (100%) reported that wound irrigation and debridement occurs most frequently in the operating room (OR; Table 3). Injuries of all severities tended to receive operative debridement within 24 hours of patient presentation, with the specific distribution by injury severity shown in Fig. 1. The reported time from presentation to debridement for GA-I/II fractures was most commonly 6–24 hours (63.4%) or <6 hours (18.5%) for LIC/LMIC surgeons, compared with 6–24 hours (54.7%) and 24–48 hours (28.3%) for UMIC surgeons. The difference in time to debridement disappeared in GA-III fractures. Delays to debridement in LIC/LMICs were often attributed to delays in patients reaching care[20] (50%–51%) while in UMICs, delays were most significant after presentation and before delivery of care (53%–58%). The most common causes of delays after presentation differed based on the country income level. LIC/LMIC surgeons reported challenges with equipment availability (12%–15%), excessive cost to the patient (11%–14%), and OR availability (13%–15%) while UMIC surgeons predominantly reported OR availability (42%–53%) and, to a lesser extent, nursing availability (11%–13%).

3.3. Domain 2: Antibiotic Administration

Most of the participants from both LIC/LMICs (97.6%) and UMICs (100%) reported treating all open tibial shaft fractures with prophylactic antibiotics (Table 4). In both practice settings, participants confirmed tetanus vaccination status of patients with open tibial shaft fractures, but rates of doing so were lower among LIC/LMIC participants (85.6% compared with 98.1%). Across

TABLE 2
Country of Employment

	Total (N = 261)
Benin	5 (1.9%)
Botswana	1 (0.4%)
Burkina Faso	2 (0.8%)
Burundi	2 (0.8%)
Cameroon	6 (2.3%)
Central African Republic	1 (0.4%)
Democratic Republic of the Congo	4 (1.5%)
Republic of the Congo	3 (1.2%)
Egypt	1 (0.4%)
Ethiopia	18 (6.9%)
Gabon	3 (1.2%)
Gambia	3 (1.2%)
Ghana	13 (5%)
Guinea	1 (0.4%)
Ivory coast	3 (1.2%)
Kenya	11 (4.2%)
Liberia	1 (0.4%)
Malawi	40 (15.3%)
Mozambique	1 (0.4%)
Niger	2 (0.8%)
Nigeria	21 (8.1%)
Rwanda	3 (1.2%)
Senegal	3 (1.2%)
South Africa	49 (18.8%)
South Sudan	2 (0.8%)
Sudan	5 (1.9%)
Tanzania	27 (10.3%)
Togo	5 (2%)
Uganda	7 (2.7%)
Zambia	6 (2.3%)
Zimbabwe	12 (4.6%)

practice setting and injury severity, the most common method of antibiotic administration was intravenous administration, but LIC/LMIC surgeons also reported administering significantly more oral antibiotics (12%–17% LIC/LMIC compared with 0% UMIC). Regarding the timing of antibiotic administration, a slight majority of patients were reported to receive their first dose of antibiotics within 3 hours of presentation (55%–61% < 3 hours, 39%–45% ≥ 3 hours).

The most common reasons for delayed antibiotic administration differed across practice settings. Barriers reported by LIC/LMIC surgeons included cost to the patient (47.1%), lack of antibiotic availability (26%), and nursing delays in administering antibiotics (23.1%) while UMIC surgeons reported mostly personnel delays, both in ordering by physicians (39.6%) and administration by nurses (35.9%).

LIC/LMIC participants reported higher usage of third-generation cephalosporins (67%–78% compared with 4%–8% in UMICs), metronidazole (24%–31% compared with 0%–15% in UMICs), and flucloxacillin (10%–13% compared with 0%–2% in UMICs) for patients with any open tibial fracture. UMIC participants relied more heavily on first-generation cephalosporins (60%–85% compared with 9%–17% in LIC/LMICs), and when treating GAI-III fractures, also reported using amoxicillin/clavulanic acid more frequently (34% compared to 16% in LIC/LMICs).

Duration of antibiotic prescription differed significantly by practice setting (Fig. 2); for GA-I/II fractures, over 3 quarters of LIC/LMIC participants continued antibiotic administration for >24 hours after wound closure (81% compared with 36% in UMICs), with almost half continuing antibiotics for greater than 4 days (43.4% compared with 9.6% in UMICs). For GA-III fractures, an even larger proportion of LIC/LMIC surgeons continued antibiotic administration for greater than 4 days (61.3% compared with 17% in UMICs) while UMIC surgeons most frequently continued antibiotics for 1–3 days (51% compared with 28% in LIC/LMICs). Regardless of injury severity, LIC/LMIC surgeons more regularly discharged patients with oral antibiotics (65%–83% compared with 23%–26% for UMICs).

3.4. Domain 3: Fracture Fixation

Internal fixation (encompassing both plate and screw fixation as well as intramedullary nailing) was the most common treatment method for all fractures in all practice settings (Table 5, Fig. 3). However, some LIC/LMIC respondents reported only having access to external fixation (11.1% compared with 3.8% in UMICs), and one-sixth reported having access to neither internal nor external fixation (16.4% compared with 0% in UMICs). Respondents who reported no access to internal fixation almost exclusively practiced in LIC/LMICs and reported lack of equipment (12% compared with 0% UMIC) and limited experience (16.8% compared with 3.8% UMIC) as the primary reasons they did not use internal fixation. Respondents who reported no access to internal or external fixation were exclusively from LIC/LMICs, and similar proportions cited lack of equipment (8.2%) and limited experience (6.3%) as their reasons. Of participants who perform internal fixation for any fractures, UMIC surgeons almost exclusively used intramedullary nailing for GA-I/II fractures (94.1% compared with 65% LIC/LMIC) that presented acutely (within 24 hours after injury) while LIC/LMIC surgeons also relied

TABLE 3
Irrigation and Debridement Patterns by World Bank Classification

Characteristic	World Bank Classification	
	LIC/LMIC	UMIC
Location of wound irrigation and debridement	N = 197	N = 51
ED or hospital ward	11 (5.6%)	0
OR (± initial washout in ED)	186 (94.4%)	51 (100%)
Time from presentation to first debridement in OR*	N = 402	N = 106
<6h	99 (24.6%)	14 (13.2%)
6–24h	239 (59.4%)	62 (58.5%)
24–48h	51 (12.7%)	23 (21.7%)
>48h	13 (3.2%)	7 (6.6%)
Reasons for delay in debridement*,†	N = 391	N = 104
Delays in patients seeking care (primary)	74 (18.9%)	1 (1%)
Delays in patient reaching care (secondary)	199 (50.1%)	45 (43.2%)
Delays in patient receiving care (tertiary)	118 (30.2%)	58 (55.8%)
Reasons for delays in receiving care‡	N = 208	N = 53
Operating theatre rooms not available*,†	42 (20.2%)	28 (52.8%)
Equipment, supplies, meds, and/or implants not available*,†	41 (19.7%)	0
Patient ability to pay*,†	31 (14.9%)	0
Patient condition (polytrauma, medical comorbidities)	26 (12.5%)	5 (9.4%)
Anesthesia staff not available	20 (9.6%)	5 (9.4%)
Nursing or other staff not available*,†	6 (2.9%)	8 (15.1%)
Surgeon not available	4 (1.9%)	0
Surgeon choice*	1 (0.5%)	3 (5.7%)
Other	3 (1.4%)	1 (1.9%)

* Signifies a result that was significantly different between LIC/LMICs and UMICs for GA-I/II injuries.
† Signifies a result that was significantly different between LIC/LMICs and UMICs for GA-III injuries.
‡ Signifies a question for which multiple responses were possible. For questions that were asked of GA-I/II and GA-III injuries, responses were grouped by World Bank classification, and the reported numbers and percentages encompass both levels of injury severity.

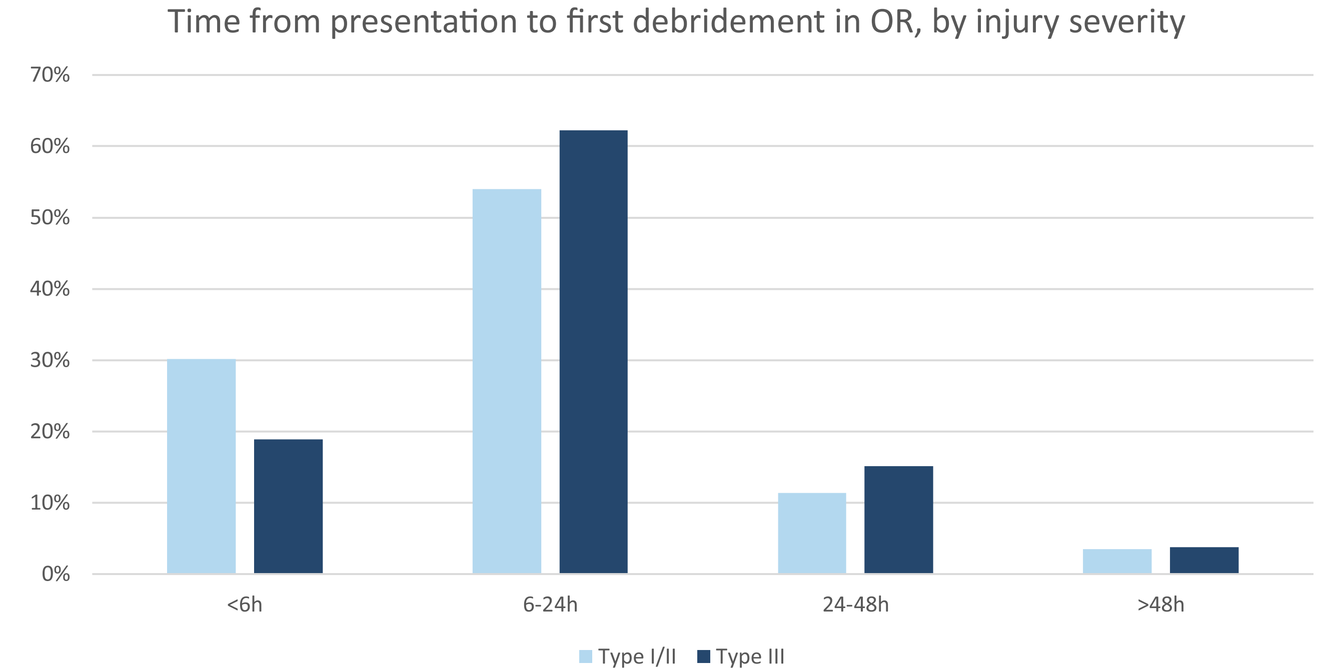

FIGURE 1. Time from presentation to first operative debridement, by injury severity.

on casting and splint immobilization (16.1% compared with 2% UMIC) and external fixation (16.1% compared with 3.9% UMIC). For GA-III fractures that presented acutely, LIC/LMIC surgeons predominantly used external fixation (63.3% compared with 31.4% UMIC) while UMIC surgeons preferred intramedullary nailing (68.6% compared with 31.3% LIC/LMIC). For fractures that presented late (>3 days after injury), respondents preferred external fixation to intramedullary nailing, regardless of the practice setting and injury severity, although UMIC respondents used intramedullary nailing more frequently for delayed GA-I/II fractures (41.2% compared with 21.7% LIC/LMIC).

When internal fixation was used, respondents from LIC/LMICs preferred completing internal fixation at the time of initial debridement for acutely presenting fractures (62.4% of GA-I/II and 58.3% of GA-III fractures), and preferred delaying internal fixation until a subsequent surgery for fractures presenting >3 days after injury (70.6% of GA-I/II and 90.9% of GA-III) (Fig. 4). UMIC respondents also preferred completing internal fixation with initial debridement for all acute fractures (81.3% GA-I/II and 70.6% GA-III), but the decision to delay internal fixation for fractures presenting late varied by injury severity, with two-thirds of GA-I/II fractures receiving internal fixation at the time of initial debridement, compared with one-third of GA-III fractures. If internal fixation was performed in a delayed fashion, respondents did not significantly favor casting or external fixation as a method of initial stabilization.

Participants were also asked what factors most influenced their decision to avoid internal fixation when managing an open tibial shaft fracture. The most common reasons in all practice settings included severity of soft-tissue injury, degree of contamination, and time from injury to debridement (Fig. 5).

4. Discussion

To the best of our knowledge, this is the first study to examine patterns of preferred treatment of open tibial fractures in a cohort of sub-Saharan African providers of orthopaedic trauma care. We specifically explored domains of irrigation and debridement, antibiotic administration, and fracture fixation and identified differences in treatment patterns among African UMICs compared with LMICs and LICs. We also identified potentially modifiable factors that, if addressed, may improve open fracture treatment in these practice settings.

We found that LIC/LMIC respondents were less likely than UMIC respondents to have confirmed the tetanus vaccination status of patients presenting with an open tibial shaft fracture. The incidence of tetanus has been declining worldwide and mortality in developed countries is less than 0.02 per 100,000 people per year,[21] but the case fatality rate is disproportionately high in Africa,[22,23] where over 1/3 of global deaths attributable to tetanus occurred. The causes for this increased disease burden are multifactorial and include climate and geographic factors; inadequate wound care[22]; less robust vaccination programs, particularly for remote rural populations[24]; and decreased access to rapid and cost-effective testing modalities.[25] While our study did not explore the incidence of tetanus in patients with open tibial fractures, the disparity in tetanus screening between country income levels suggests that setting standardized testing protocols for any patients presenting with open fractures may address a current gap in fracture care in some practice settings.

We found that there was no significant difference in time from presentation to first antibiotic administration across practice settings. However, when delays to antibiotic administration did occur, in LIC/LMIC practice settings, they were significantly more likely to be due to resource limitations such as patient inability to afford treatment and antibiotic availability, rather than workflow delays in ordering, delivering, or administering antibiotics. There is wide variation in health insurance coverage in African countries due to barriers such as large rural populations and informal sectors of employment.[26,27] In the absence of formal health insurance and risk-pooling mechanisms, households in LMICs often must borrow or sell assets to afford large out-of-pocket expenses.[10,28,29]

TABLE 4

Antibiotic Administration by World Bank Classification

Characteristic	World Bank Classification					
		LIC/LMIC			UMIC	
		N = 207			N = 52	
Treat all open tibial shaft fractures with prophylactic antibiotics		202 (97.6%)			52 (100%)	
		N = 208			N = 53	
Confirm up-to-date tetanus vaccine*		178 (85.6%)			52 (98.1%)	
	I/II		III	I/II		III
Method of antibiotic delivery†		N = 208			N = 53	
IV Antibiotics	195 (93.8%)		195 (93.8%)	53 (100%)		53 (100%)
Oral antibiotics‡,§	36 (17.3%)		25 (12%)	0		0
Local antibiotics (eg, beads or powder)	5 (2.4%)		13 (6.3%)	1 (1.9%)		2 (3.8%)
IM Antibiotics	9 (4.3%)		8 (3.9%)	0		0
Other	1 (0.5%)		2 (1%)	0		0
Time from presentation to first antibiotics*	N = 203		N = 205	N = 53		N = 53
<3 h	111 (54.7%)		124 (60.5%)	31 (58.5%)		31 (58.5%)
≥3 h	92 (45.3%)		81 (39.5%)	22 (41.5%)		22 (41.5%)
Reason for delayed antibiotic administration		N = 208			N = 53	
Patient cannot afford to pay*		98 (47.1%)			3 (5.7%)	
Antibiotic not available*		54 (26%)			3 (5.7%)	
Nursing delay in administering antibiotic		48 (23.1%)			19 (35.9%)	
Physician delay in ordering antibiotic*		30 (14.4%)			21 (39.6%)	
Pharmacy delay in delivering antibiotic		24 (11.5%)			4 (7.6%)	
Other (ED/trauma bay delays)		1 (0.5%)			4 (7.6%)	
Other (administrative/processing delays)		1 (0.5%)			1 (1.9%)	
	I/II		III	I/II		III
Typical antibiotic regimen for noncontaminated open fractures		N = 208			N = 53	
1st Generation cephalosporin‡,§	35 (16.8%)		18 (8.7%)	45 (84.9%)		32 (60.4%)
3rd Generation cephalosporin‡,§	139 (66.8%)		162 (77.9%)	2 (3.8%)		4 (7.6%)
Aminoglycoside	34 (16.4%)		59 (28.4%)	4 (7.6%)		19 (35.9%)
Penicillin	11 (5.3%)		10 (4.8%)	0		2 (3.8%)
Amoxicillin/Clavulanic acid§	36 (17.3%)		33 (15.9%)	8 (15.1%)		18 (34%)
Metronidazole‡,§	49 (23.6%)		64 (30.8%)	0		8 (15.1%)
Clindamycin	6 (2.9%)		10 (4.8%)	1 (1.9%)		3 (5.7%)
Flucloxacillin‡,§	28 (13.5%)		21 (10.1%)	1 (1.9%)		0
Other	8 (3.9%)		7 (3.4%)	0		0
Duration of antibiotics after wound closure‡,§	N = 205		N = 204	N = 52		N = 53
Up to 24 h	38 (18.5%)		22 (10.8%)	33 (63.5%)		17 (32.1%)
1–3 d	78 (38.1%)		57 (27.9%)	14 (26.9%)		27 (50.9%)
Greater than 4 d	89 (43.4%)		125 (61.3%)	5 (9.6%)		9 (17%)
	N = 206		N = 203	N = 52		N = 53
Discharge with oral antibiotics‡,§	176 (65.4%)		169 (83.3%)	12 (23.1%)		14 (26.4%)

* Signifies a result that was significantly different between LIC/LMICs and UMICs, for questions that were asked without respect to injury severity.
† Signifies a question for which multiple responses were possible.
‡ Signifies a result that was significantly different between LIC/LMICs and UMICs for GA-I/II injuries.
§ Signifies a result that was significantly different between LIC/LMICs and UMICs for GA-III injuries.

Our study contributes to the well-documented evidence of limited antimicrobial access in LMICs[30–32] and provides novel insight into the impact of these resource limitations on standards of orthopaedic trauma care in sub-Saharan Africa. Reducing cost and improving access to antibiotics is an enormous, multidisciplinary undertaking, but some proposed financial mechanisms include offering nominal licenses to LMIC manufacturers and using benchmark payments from HICs to support selling antibiotics at production cost in LMICs.[30,31] Methods to increase antimicrobial access will also need to be coupled with substantive health system strengthening[30,33] and effective oversight to address antibiotic stewardship and antibiotic resistance.[31,32]

Our study took the "three-delay" model initially described by Thaddeus and Maine[20] for maternal mortality in developing countries and applied it to timeliness of fracture care. The original framework defines a primary delay as delay in seeking care by the individual or family, a secondary delay as delay in reaching a healthcare facility, and a tertiary delay as a delay in receiving adequate care after arriving at a healthcare facility. Our study found that LIC/LMIC respondents most frequently reported secondary delays (delays in reaching a hospital) while UMIC respondents reported tertiary delays (delays in receiving care after arriving at a hospital). This difference in the type of delay had implications for treatment decisions because LMIC surgeons were even more likely to use staged treatment with an initial debridement, followed by a subsequent operative fixation if patients presented late. The impact of staged treatment on risk of infection and nonunion and on cost of care has not been well-documented and requires further research.[34] While most research assessing trauma care systems in LMICs has focused on tertiary

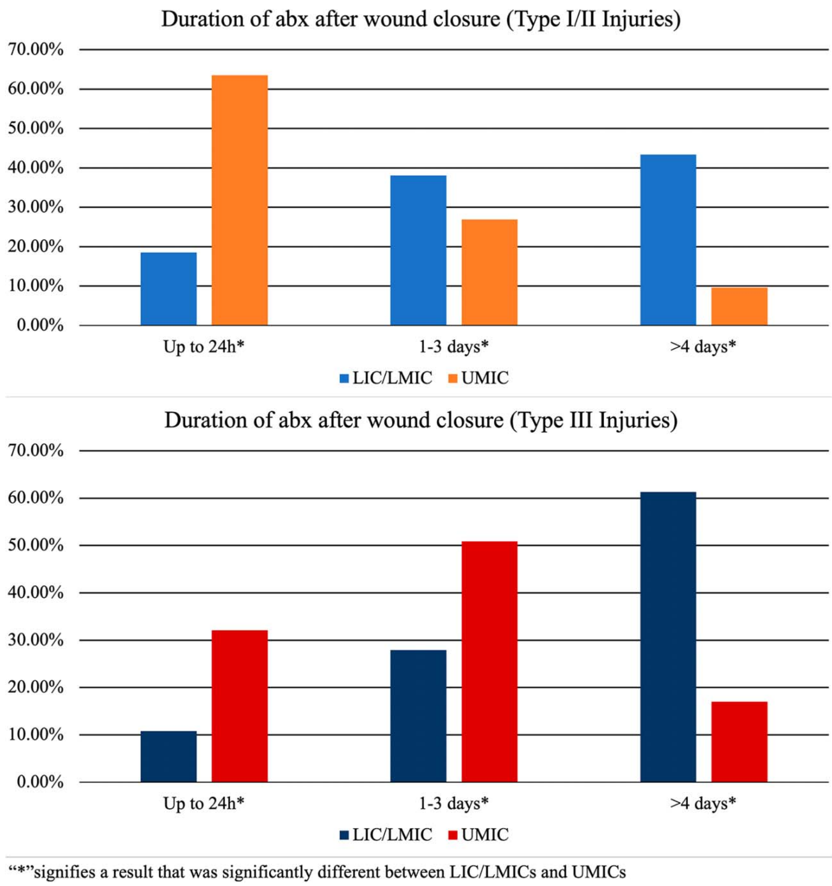

FIGURE 2. Typical duration of antibiotics after wound closure for LIC/LMIC versus UMIC, by injury severity.

delays within the healthcare facility,[35] prehospital trauma care is an important component of reducing mortality, especially in rural environments.[36] Our study did not explore the specific causes of secondary delays experienced by respondents, but some previously identified barriers in LMIC trauma systems that are both high-impact and potentially modifiable include lack of accessible emergency communication centers, timely and affordable emergency transport, and a lack of emergency care service coordination and standardized training.[37,38]

We found differences in operative fixation techniques between LIC/LMICs and UMICs. Fewer respondents in LIC/LMICs reported having the ability to perform internal fixation or external fixation at their institution. Of the respondents who could perform internal fixation, those from LIC/LMICs were more likely than their UMIC counterparts to use external fixation over intramedullary nailing for most open tibia fractures, regardless of injury severity or timing of presentation. Our results are consistent with previous studies that found that hospitals in these countries still face widespread deficiencies in trauma capacity,[39] and limited implant availability may be a key contributor.[40] However, these differences in preferred treatment could be because of lack of access to equipment and/or inadequate dissemination of knowledge, as intramedullary nailing has become an increasingly available method of fracture fixation in low-resource settings[41] and has been shown to be cost-effective[42,43] with improved early functional recovery and lower risk of malunion in LMICs.[44] Respondents reported not having sufficient experience with the procedures, not having the necessary equipment, or a combination of both, but our survey was not designed to detect whether one reason was more predominant than the other. We also found that, regardless of the practice setting, injury characteristics were a stronger driver of the decision to perform internal fixation, rather than implant cost or experience with the procedure. This suggests that these treatment preferences may reflect the epidemiology of injuries in these practice settings[45–47] rather than limitations in equipment availability, but further research will need to explore the country-specific local factors that influence these decisions.

Particularly in the domain of antibiotic administration, we identified several differences in the treatment pattern that did not

TABLE 5

Fixation Patterns by World Bank Classification

	LIC/LMIC	UMIC
Fixation techniques available at hospital for all fractures*	N = 208	N = 53
Internal fixation	151 (72.6%)	51 (96.2%)
External fixation only	23 (11.1%)	2 (3.8%)
Neither internal nor external fixation	34 (16.4%)	0
Not all respondents answered all questions		
Typical method of initial stabilization for open tibia fractures with planned definitive internal fixation in a delayed fashion	N = 83	N = 21
Cast or splint	40 (48.2%)	11 (52.4%)
External fixation	43 (51.8%)	10 (47.6%)

For questions that were asked without respect to injury severity.
* Signifies a result that was significantly different between LIC/LMICs and UMICs.

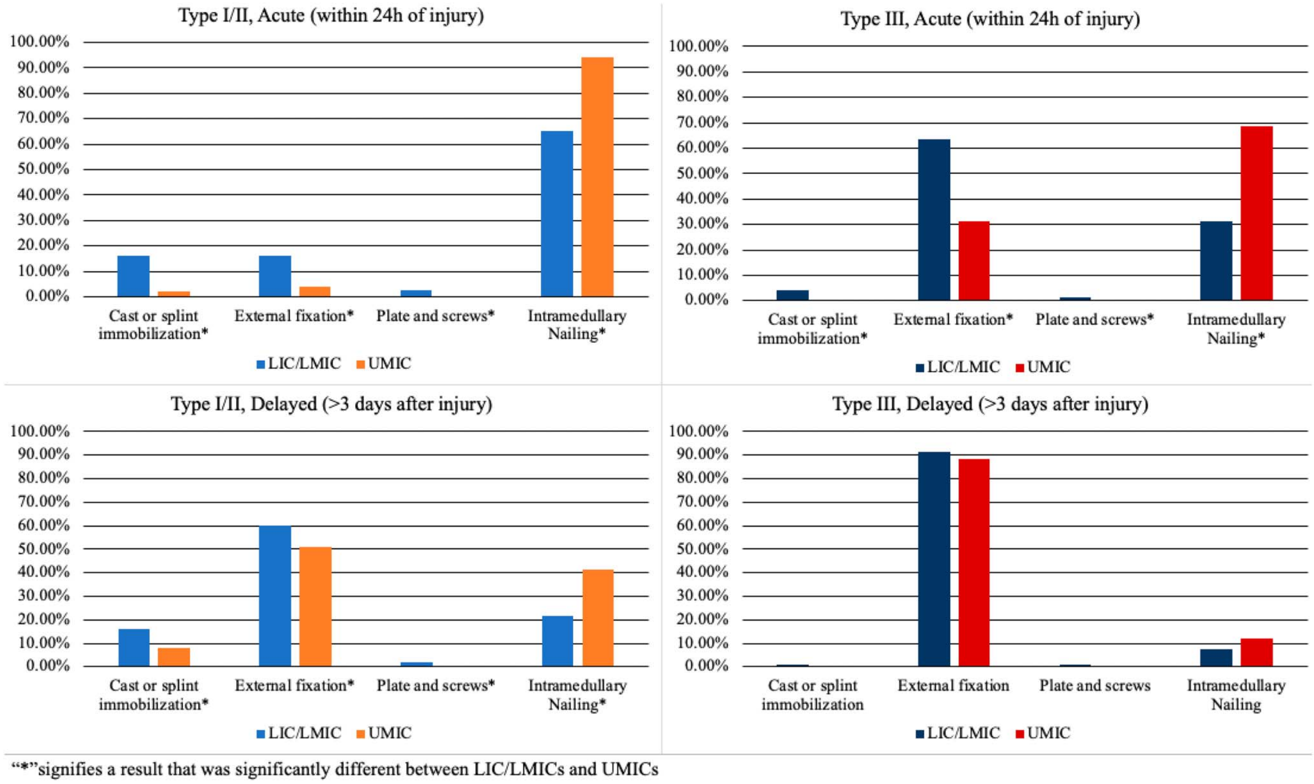

FIGURE 3. Typical management of open tibial shaft fracture by World Bank classification, based on injury severity and acuity of presentation.

necessarily reflect a deficiency in one practice setting versus another. Choice of antibiotic regimen in UMICs closely reflected that of the global north, where first-generation cephalosporins are the most widely prescribed antibiotic for orthopaedic trauma.[48,49] LIC/LMIC settings more often prescribed third-generation cephalosporins or metronidazole, regardless of injury severity. A study of

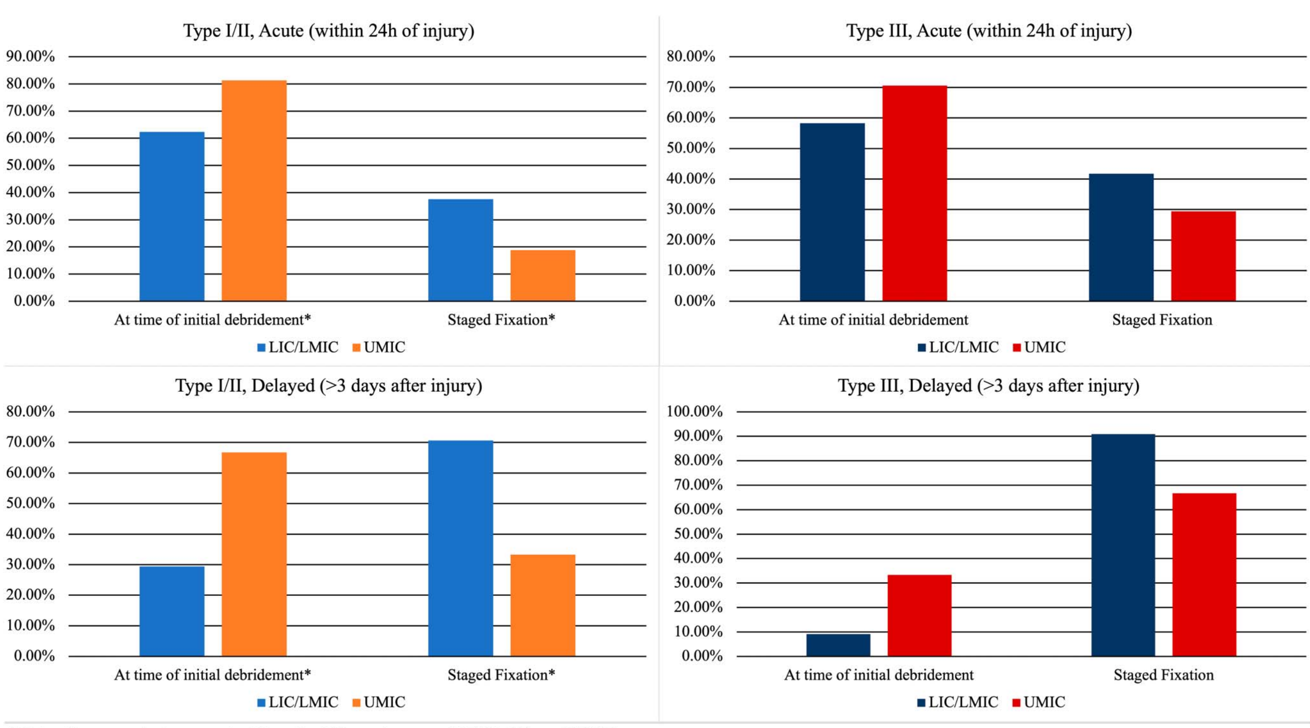

FIGURE 4. Timing of definitive fixation of open tibial shaft fractures by World Bank classification, based on injury severity and acuity of presentation.

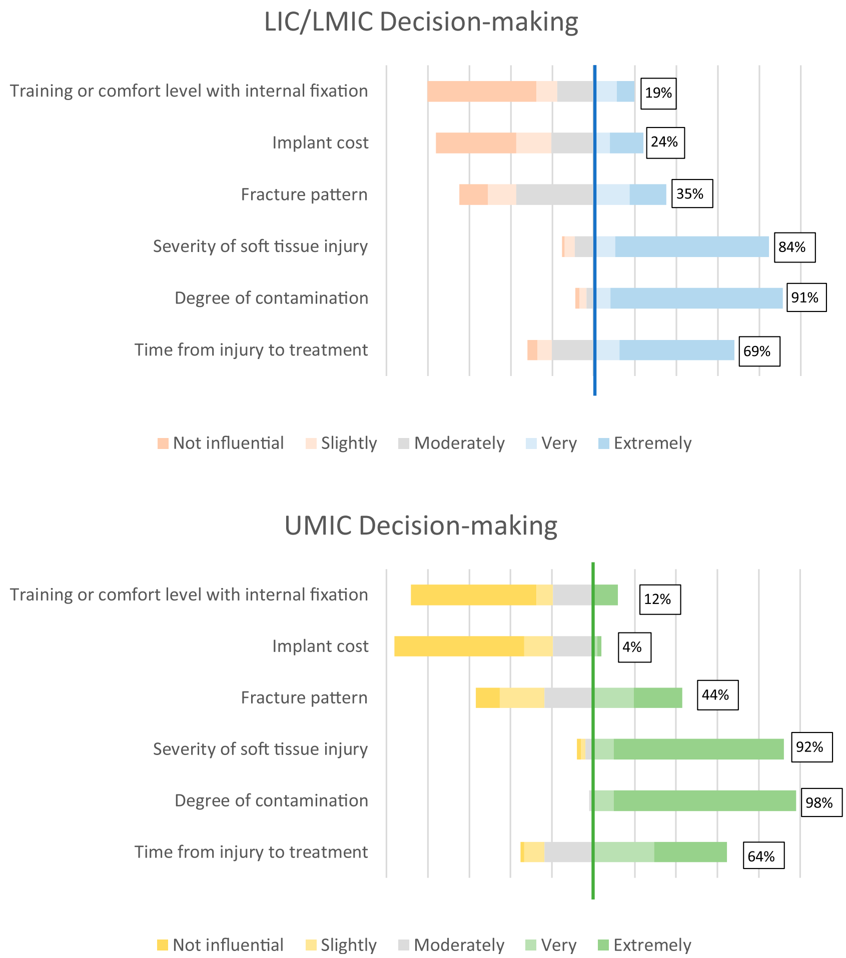

FIGURE 5. Factors that influence respondent's decision whether to perform internal fixation, by World Bank classification.

68 patients at a referral hospital in Ethiopia also found that a combination of ceftriaxone and metronidazole was the most commonly prescribed regimen.[50] A recent randomized, open-label trial compared ceftriaxone with cefepime for 230 patients undergoing elective orthopaedic surgery in Tanzania and found no significant difference in the prevention of SSIs.[51] Although our study did not assess the underlying reasons for selecting a particular antibiotic regimen, it is possible that ceftriaxone is favored in LIC/LMICs for its low cost and convenience of once-daily dosing. To the best of our knowledge, no study has compared the efficacy of first and third-generation cephalosporins in a developing country, and a future pragmatic trial could be useful in determining which regimen is most appropriate for these practice settings.

We also found that the duration of antibiotic administration after wound closure varied by practice setting. Current clinical guidelines in the United States recommend a single dose of an antimicrobial agent for no more than 24 hours[49,52] and advise against prolonging postoperative antibiotic prophylaxis due to a lack of any supplementary benefit and the risk of promoting the growth of drug-resistant pathogens.[53–57] We found that antibiotics were typically prescribed for >4 days after wound closure, regardless of injury severity in LIC/LMICs, while in UMICs antibiotics were usually prescribed for less than 1 day for GA-I/II injuries and for 1–3 days for GA-III injuries. A recent Ethiopian study that examined surgical antimicrobial prophylaxis patterns at a tertiary care teaching hospital found that most patients received antibiotics for greater than 72 hours after surgery, and only 4% received antibiotics for less than 24 hours.[58] In a basic science study of a contaminated rabbit fracture, a 72-hour course of intravenous cefuroxime was found to be superior to single-shot or 24-hour regimens in preventing fracture-related infections,[59] but there has been little clinical research recommending prolonged postoperative courses of antibiotics.[55,56] The ideal duration of postoperative antibiotics is controversial in all practice settings, but particularly in LIC/LMICs, a rigorous randomized controlled trial is needed to determine the best protocol given the specific socioeconomic challenges faced in these settings.

This study has several limitations. Owing to the mixed methodology used to distribute the survey, including both convenience sampling from academic coalitions and snowball sampling, we were unable to obtain a response rate for the survey. This mixed methodology may have reduced the selection bias for surgeons who are connected to international academic networks, but there is, nonetheless, a bias toward surgeons practicing at tertiary hospitals in urban settings, particularly in countries where we had high response rates such as South Africa, where resource availability differs greatly in rural and urban practice settings. There is also the possibility for self-reporting bias, as individual surgeons and clinical officers were asked to provide estimates for time to treatment and primary causes for delay based on their anecdotal experiences, rather than data that were formally collected by themselves or their institution.

5. Conclusion

Our study sought to describe open tibial fracture treatment patterns by orthopaedic surgeons and healthcare practitioners across Africa. We determined that there are significant differences particularly pertaining to antibiotic administration and fracture fixation among African UMICs and LIC/LMICs. Further research will need to clarify the underlying causes of these discrepancies and to establish locally applicable guidelines.

Appendix 1. Collaborative Authorship—Orthopaedic Research Collaboration in Africa (ORCA)

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