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Article in *The Journal of Bone and Joint Surgery* · February 2025

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Risk Factors for Amputation and Prolonged Hospitalization Among Children Who Received Traditional Bonesetting in Ethiopia

Ephrem G. Adem, MD, Papa K. Morgan-Asiedu, MD, MPH, Mengistu G. Mengesha, MD, Mario Keko, DrPH, MPH, Chen Mo, DrPH, Sintayehu Bussa, MD, Eden Alemu, MSc, Yishak Zerihun, MD, Habtamu T. Derilo, MD, Mahamed Areis, MD, Kaleab T. Reda, MD, Wubshet A. Workneh, MD, Bahru A. Shiferaw, MD, Moa C. Jira, MD, Habtamu B. Gula, MD, Mulugeta B. Geneti, MD, Claude Martin Jr., MD, MBA, Kiran J. Agarwal-Harding, MD, MPH*, and William J. Harrison, MD*

Background: In Ethiopia, orthopaedic services are limited, and many injured children undergo traditional bonesetting (TBS) despite its association with limb- and life-threatening complications. We sought to identify the risk factors for amputation and a prolonged hospitalization of >7 days in children who presented to hospitals after undergoing TBS.

Methods: Over a 15-month period, we prospectively enrolled children who presented to 8 Ethiopian hospitals after undergoing TBS. Separately for each outcome (amputation and prolonged hospitalization), we used multivariable logistic regression to evaluate associations between the outcome and 16 covariates, including demographic and injury characteristics, parent or guardian preference for TBS, and TBS topical treatments and immobilization methods.

Results: We enrolled 460 children (mean age, 9.0 ± 4.0 years; 75% male) representing 8 Ethiopian regions and diverse demographic and socioeconomic backgrounds. Elbow injuries (194 patients; 42.2%) and closed fractures and/or dislocations (364 patients; 79.1%) were most common. TBS treatments included topical inorganic (190 patients; 41.3%) or organic (82 patients; 17.8%) material application and rigid (166 patients; 36.1%) or soft (182 patients; 39.6%) immobilization. Twenty-six children (5.7%) underwent an amputation, and 102 (22.2%) had a prolonged hospitalization. The odds of amputation were higher for children from rural communities (adjusted odds ratio [AOR], 6.71; 95% confidence interval [CI], 2.01 to 22.41) and for children with only non-osseous injuries (AOR, 5.76; 95% CI, 1.56 to 21.28). The odds of prolonged hospitalization were higher for children who were 11 to 17 years old (AOR, 2.77; 95% CI, 1.18 to 6.50) and for children with open fractures with a grade of ≥ 2 (AOR, 4.52; 95% CI, 1.33 to 15.28) but were lower for children from households with secondary education or higher (AOR, 0.40; 95% CI, 0.21 to 0.79). TBS with rigid immobilization increased the odds of amputation (AOR, 5.84; 95% CI, 1.74 to 19.60) and prolonged hospitalization (AOR, 2.20; 95% CI, 1.02 to 4.73). TBS organic topical treatment (with mud, leaves, or butter) increased the odds of amputation (AOR, 3.88; 95% CI, 1.40 to 10.73).

Conclusions: For children who underwent TBS prior to hospital presentation, rigid splinting by bonesetters increased the odds of amputation and prolonged hospitalization. TBS organic topical treatments also increased the odds of amputation. Training bonesetters to avoid these dangerous practices may prevent devastating complications for children in Ethiopia.

Level of Evidence: Prognostic Level III. See Instructions for Authors for a complete description of levels of evidence.

Despite advances in the quality and availability of health services in low- and middle-income countries, traditional healing practices remain widely utilized¹⁻⁸. Traditional bonesetting (TBS) is popular for the management of musculoskeletal injuries in many sub-Saharan African countries¹⁻⁶. In Ethiopia, a low-income East African

country with 123 million people⁹, >80% of people rely on traditional medicine due to inadequate health-care capacity, especially in rural areas^{7,10-12}. With a growing trauma burden and shortage of surgeons in Ethiopia, many Ethiopians continue to patronize traditional bonesetters for musculoskeletal care^{10,13-16}.

*Kiran J. Agarwal-Harding, MD, MPH, and William J. Harrison, MD, contributed equally to this work.

Disclosure: This study was funded by the AO Alliance Foundation. The **Disclosure of Potential Conflicts of Interest** forms are provided with the online version of the article (<http://links.lww.com/JBJS/I418>).

Although bonesetters can provide accessible and cheaper care relative to that provided by orthopaedic surgeons, they have no formal training in anatomy, physiology, or infection prevention^{1,4-6,17-24}. Studies have linked TBS practices—namely, blind manipulations and massage, bamboo or wooden splints (Fig. 1), herbal concoctions, and scarifications^{2-6,22-28}—to complications such as malunion, nonunion, compartment syndrome, tetanus, chronic osteomyelitis, gangrene, amputation, sepsis, and even death, including among children^{8,13,17-20,22,25,27,29-36}. While some researchers and surgeons have advocated for the eradication of TBS practices⁴, others have attempted to integrate bonesetters into the allopathic health system^{2,3,17,18,28,35,37}. The risks of TBS in children are incompletely understood³⁷. Most of the studies that have examined TBS-associated complications were single-center, small, retrospective case series^{1,5,17,18,26,29,32,38}.

The Bone Setting Associated Disability (BOSAD) Study is a multipart, multicenter Ethiopian study investigating TBS practices and associated complications. As part of this project, we assessed the demographics, injury characteristics, and complications among children presenting to a hospital after undergoing TBS. We also assessed the risk factors for amputation and prolonged hospitalization, with the assumption that severe complications may lead to these outcomes.



Fig. 1
A bamboo splint and dressing applied by a traditional bonesetter.

Materials and Methods

Study Design and Setting

This prospective observational study was conducted at 8 tertiary hospitals in Ethiopia (Fig. 2). The institutional review board of Hawassa University approved the study (IRB/280/12). From July 2021 to September 2022, all children (age <18 years) seen by orthopaedic providers in emergency or outpatient departments were screened for study inclusion. All children who presented to a BOSAD study hospital for an injury for which they had reportedly undergone a prior TBS treatment were recruited. Informed consent was obtained from parents or guardians, who completed enrollment surveys with the assistance of trained BOSAD data collectors fluent in the dominant local language. Medical interpreters were available when needed. We recorded patient demographics, household socioeconomic background, injury characteristics, prior visits to other health facilities, TBS treatments, and parent or guardian perspectives and/or preferences regarding TBS. Complications that were present at enrollment, as well as subsequent treatment at a BOSAD study hospital, were recorded. For patients requiring admission, the hospital course and outcome at discharge were recorded.

Data Elements

Our outcomes of interest were amputation and hospitalization longer than the median duration in the cohort (7 days). We examined 16 covariates that were plausibly associated with these outcomes, based on clinical experience and a literature review: age, sex, highest household education level, poverty status, residence type (rural or urban), geographic region, injury mechanism, injured body part, injury type, fracture displacement, time to presentation, parent or guardian preference for TBS at the time of injury, parent or guardian preference for TBS for future injuries, visit to a health facility before undergoing TBS, TBS topical treatment, and TBS immobilization method performed^{6,7,13,14,19,24,25,27,33,34,39-41}.

We categorized age as 0 to 5 years, 6 to 10 years, or 11 to 17 years. We categorized household education level as no education (cannot read or write), informal education (literate without formal education), primary school (grades 1 to 8), secondary school (grades 9 to 12) or higher, or unknown. We estimated the income per person per month by dividing the household monthly income by the number of household members (including the patient), and we determined poverty status with use of the poverty line of 913 Ethiopian birr per person per month, which is equivalent to the 2022 World Bank poverty level of \$2.15 per day (converted using a purchasing power parity ratio of 14.2)⁹. Five geographic regions were included: Amhara; Oromia; Sidama; Southern Nations, Nationalities and Peoples' Region (SNNPR); and Somali. Regions with small sample sizes—Benishangul-Gumuz, Dire Dawa, and Harari—were grouped with the nearby regions of Amhara, Somali, and Oromia, respectively.

The injury mechanisms are listed in Appendix A.1. The injured body part (see Appendix A.2) was categorized as shoulder/arm, elbow, forearm/wrist/hand, hip/thigh/knee, or leg/ankle/foot. Injury type and fracture displacement status were determined by the treating physicians on the basis of the examination and radiographs at study enrollment. The injury types included closed

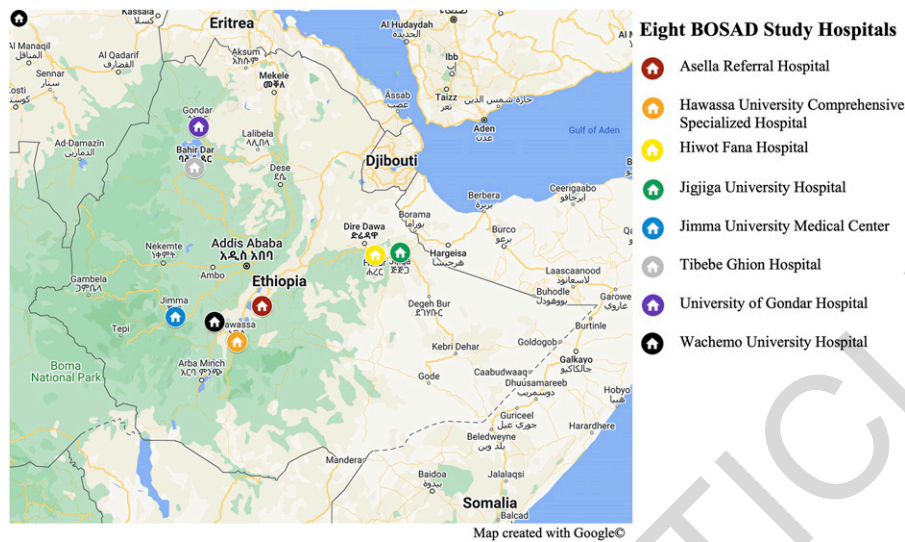


Fig. 2
Map of the 8 BOSAD study hospitals. Reproduced with permission.

fractures and/or dislocations, open fractures (classified with the Gustilo-Anderson grade), and non-osseous injuries (i.e., ligamentous, muscular, or skin injuries). The time from injury to presentation at a study center was categorized as ≤ 14 , 15 to 28, or > 28 days. Patient-reported TBS methods included rigid (bamboo, wooden, or metal splint) or soft (towel, leather splint, or other soft dressing) immobilization, and organic (mud, leaf, plant ingredient, or butter) or inorganic (petroleum jelly or another chemical or drug) topical treatment.

Statistical Analysis

Separately for each outcome (amputation and prolonged hospitalization), we examined the association between the outcomes and each covariate. After performing bivariate screening with use of logistic regression, we performed a multivariable analysis that included all covariates that had a Type-III p value of < 0.1 in the bivariate screening, were considered clinically important, and/or were likely modifiers of significant covariates. Final parsimonious models were constructed by removing covariates with low significance ($p > 0.1$). Clinically relevant covariates were retained, and we checked for multicollinearity. The level of significance was set at $p < 0.05$. The analysis was performed with use of R (version 4.3.1; R Foundation for Statistical Computing).

Results

We enrolled 460 children with a mean age (and standard deviation) of 9.0 ± 4.0 years. Our cohort was mostly male (343 patients; 74.6%) and represented 8 geographic regions, including Oromia (170 patients; 37.0%), Amhara (85 patients; 18.5%), and SNNPR (82 patients; 17.8%), with nearly equal representation of urban (242 patients; 52.6%) and rural (218 patients; 47.4%) communities. The children were predominantly from Ethiopian Orthodox (159 patients; 34.6%), Muslim (194 patients; 42.2%), and Protestant (104 patients; 22.6%) households. Among patients for whom the highest household

education was known, the education level was distributed as follows: no education (65 patients; 14.1%), informal education (56 patients; 12.2%), primary school (77 patients; 16.7%), and secondary school or higher (111 patients; 24.1%). The mean household size was 5.6 ± 2.1 people, and 316 (68.7%) of the children lived in poverty (Table I).

The median time from injury to presentation at a BOSAD center was 29 days (range, 1 day to 7.5 years). The injuries were mostly ground-level falls (171 patients; 37.2%) or falls from a height (181 patients; 39.3%) and most frequently involved the elbow (194 patients; 42.2%), forearm (71 patients; 15.4%), or leg/ankle/foot (74 patients; 16.1%). The injuries consisted of closed fractures and/or dislocations (364 patients; 79.1%), open fractures (27 patients; 5.9%), and only non-osseous injuries (69 patients; 15.0%) (Table I). Eighty-nine children (19.3%) had initially visited a health facility before undergoing TBS. Most of the patients (293; 63.7%) had parents or guardians who preferred TBS at the time of injury, and 160 (34.8%) had parents or guardians who preferred TBS for a future injury. TBS immobilization varied significantly by body part and injury type; topical treatments varied significantly by body part, but not by injury type (see Appendix B.1). Most of the children had undergone a TBS topical treatment with inorganic (190 patients; 41.3%) or organic (82 patients; 17.8%) materials and TBS with rigid (166 patients; 36.1%) or non-rigid (182 patients; 39.6%) immobilization (Table II). Almost half (205; 44.6%) of the children received a combination of immobilization and topical treatment by bonesetters.

We identified 361 children (78.5%) with complications. The most common complications were joint stiffness or contracture (232 patients; 50.4%), malunion (130 patients; 28.3%), and muscle atrophy or weakness (87 patients; 18.9%) (Table III). The median hospitalization duration was 7 days (interquartile range [IQR], 4 to 13 days; range, 0 to 127 days). Children were often admitted for surgery (249 patients; 54%). A total of 102

TABLE I Descriptive Statistics (N = 460)

Characteristic	No. (%) [*]
Age (yr)	9.0 ± 4.0
Age group (no. of patients)	
0 to 5 years	90 (19.6)
6 to 10 years	227 (49.3)
11 to 17 years	143 (31.1)
Sex (no. of patients)	
Male	343 (74.6)
Female	117 (25.4)
Patient education level (no. of patients)	
Pre-primary school†	136 (29.6)
Primary school‡	273 (59.3)
Secondary school or higher§	18 (3.9)
No education#	28 (6.1)
Informal**	5 (1.1)
Highest household education level (no. of patients)	
Primary school‡	77 (16.7)
Secondary school or higher§	111 (24.1)
No education#	65 (14.1)
Informal**	56 (12.2)
Unknown	151 (32.8)
Religion (no. of patients)	
Ethiopian Orthodox	159 (34.6)
Muslim	194 (42.2)
Protestant	104 (22.6)
Catholic	1 (0.2)
Other	2 (0.4)
Household size (including the patient) (no. of persons)	5.6 ± 2.1
Median household income†† (1,000 birr)	3.0 (2.0, 5.0)
Poverty status‡‡ (no. of patients)	
Below poverty line	316 (68.7)
Above poverty line	144 (31.3)
Time to presentation§§ (no. of patients)	
0-14 days	142 (30.9)
15-28 days	87 (18.9)
>28 days	231 (50.2)
Geographic region### (no. of patients)	
Amhara	85 (18.5)
Benishangul-Gumuz	1 (0.2)
Dire Dawa	3 (0.7)
Harari	18 (3.9)
Oromia	170 (37.0)
Sidama	60 (13.0)
SNNPR***	82 (17.8)
Somali	41 (8.9)
Residence type (no. of patients)	
Rural	218 (47.4)
Urban	242 (52.6)

continued

TABLE I (continued)

Characteristic	No. (%) [*]
Mechanism of injury (no. of patients)	
Fall from ground level	171 (37.2)
Fall from height†††	181 (39.3)
Interpersonal violence‡‡‡	30 (6.5)
Road traffic incident§§§	25 (5.4)
Other###	53 (11.5)
Injured body part* * * (no. of patients)	
Shoulder	25 (5.4)
Arm	9 (2.0)
Elbow	194 (42.2)
Forearm	71 (15.4)
Wrist	22 (4.8)
Hand	8 (1.7)
Hip	14 (3.0)
Thigh	31 (6.7)
Knee	12 (2.6)
Leg/ankle/foot	74 (16.1)
Injury type (no. of patients)	
Non-osseous injury	69 (15.0)
Closed fracture and/or dislocation	364 (79.1)
Grade-1 open fracture††††	10 (2.2)
Grade-2 open fracture††††	9 (2.0)
Grade-3 open fracture††††	8 (1.7)
Fracture displacement (no. of patients)	
No	74 (18.9)
Yes	317 (81.1)

*Values are given as the count, with the percentage of the total cohort in parentheses, except for age and household size, which are given as the mean ± standard deviation, and household income, which is given as the median with the Q1 and Q3 values in parentheses. Percentages may not sum to 100 because of rounding. †Children <4 years old and those enrolled in nursery school or kindergarten. ‡Grades 1 to 8. §Grades 9 to 12, college, technical school, professional degree, secondary degree or above. #Cannot read or write, and with no formal schooling background. **Ability to read and write but did not attend formal grade school. ††A median monthly income of 3,000 birr is approximately \$210, converted using the 2022 World Bank purchasing power parity ratio for Ethiopia of 14.2 Ethiopian birr per U.S. dollar. ‡‡Poverty status was assessed by calculating the income per person in each patient's household on the basis of the total household income and the number of household members reported. The poverty line was set at 913 birr per person per month, equivalent to the 2022 World Bank poverty level of \$2.15 per day and converted using the 2022 World Bank purchasing power parity ratio for Ethiopia of 14.2 Ethiopian birr per U.S. dollar. §§Time from initial injury to arrival at 1 of the 8 study-site hospitals. ###There were no patients in this cohort from the following regions of Ethiopia: Afar, Gambella, Tigray, Addis Ababa. ***Southern Nations, Nationalities and Peoples' Region. †††Falls from height were from higher than ground level. ‡‡‡Includes injury from a fight or assault, a bullet wound, a blast injury, or a stab injury. §§§Includes a pedestrian struck by a motorcycle or motor vehicle, a driver of a motorcycle or motor vehicle involved in a collision, or a passenger of a motorcycle or motor vehicle involved in a collision. ####Includes a sports injury, a bicycle accident, a construction-site injury, or other mechanisms of injury. ****Body part classification was performed post hoc based on the initial diagnosis; see Appendix 1.1. ††††Gustilo-Anderson open fracture classification.

TABLE II TBS Preferences and Treatments Received Prior to Study Enrollment (N = 460)

Characteristic	No. (%) of Patients*
Visited a health facility first before undergoing TBS†	89 (19.3)
TBS was the first choice at time of injury†	293 (63.7)
Prefers TBS for a future injury	160 (34.8)
TBS topical treatment	
None	188 (40.9)
Organic material‡	82 (17.8)
Inorganic material§	190 (41.3)
TBS immobilization	
No immobilization	112 (24.3)
Rigid immobilization#	166 (36.1)
Other non-rigid immobilization**	182 (39.6)

*Percentages may not sum to 100 because of rounding. †Categories are not mutually exclusive. The parents or guardians of 56 patients reported TBS as their first choice but still visited a health facility first before undergoing TBS. Similarly, the parents or guardians of 134 patients reported that TBS was not their first choice but did not visit a health facility first. ‡Organic topical materials that had been applied included mud, leaves or other plant materials, and butter. §Inorganic topical materials included petroleum jelly or some other chemical or drug. #Rigid immobilization included the use of bamboo, wooden, or metal splints. **Other non-rigid immobilization included wrapping with a towel, leather splint, or some other soft dressing.

patients (22.2%) had a prolonged hospitalization (>7 days). Twenty-six patients (5.7%) underwent an amputation, consisting of shoulder disarticulation (2 patients) or an above-elbow (8 patients), below-elbow (6 patients), above-knee (4 patients), or below-knee (6 patients) amputation. A representative case that required amputation is shown in Figure 3. See Appendices B.2 and B.3 for further details.

In the parsimonious multivariable model, children from rural communities had increased odds of amputation (adjusted odds ratio [AOR], 6.71; 95% confidence interval [CI], 2.01 to 22.41). Higher odds of amputation were observed in children with shoulder/arm (AOR, 22.56; 95% CI, 3.03 to 167.88), forearm/wrist/hand (AOR, 13.80; 95% CI, 2.59 to 73.62), or leg/ankle/foot (AOR, 6.52; 95% CI, 1.08 to 39.15) injuries compared with children with elbow injuries. The odds of amputation were higher for children with only non-osseous injuries (AOR, 5.76; 95% CI, 1.56 to 21.28) compared with children with closed fractures. A time to presentation of >28 days after the injury was associated with lower odds of amputation (AOR, 0.08; 95% CI, 0.02 to 0.29) compared with 0 to 14 days. Children whose injuries were treated by bonesetters with organic topical treatments (AOR, 3.88; 95% CI, 1.40 to 10.73) and rigid immobilization (AOR, 5.84; 95% CI, 1.74 to 19.60) had higher odds of amputation (Table IV).

The odds of prolonged hospitalization were higher for children 11 to 17 years old (AOR, 2.77; 95% CI, 1.18 to 6.50) compared

with 0 to 5 years, and were lower for children from households with secondary education or higher (AOR, 0.40; 95% CI, 0.21 to 0.79) compared with those unable to read and write. Compared with children from Oromia, those from Amhara (AOR, 0.36; 95% CI, 0.16 to 0.81), Sidama (AOR, 0.36; 95% CI, 0.14 to 0.93), and Somali (AOR, 0.03; 95% CI, 0.00 to 0.29) had lower odds of prolonged hospitalization. Higher-grade open fractures were associated with increased odds of prolonged hospitalization (AOR, 4.52; 95% CI, 1.33 to 15.28) compared with closed fractures. Compared with no immobilization, rigid immobilization by bonesetters was associated with 2.20-fold higher odds of prolonged hospitalization (95% CI, 1.02 to 4.73) (Table V).

Discussion

Of 460 children with injuries that were treated with TBS who then presented to 8 Ethiopian referral hospitals, 5.7% underwent amputations for gangrenous limbs and infections. Patients who received organic topical treatment or rigid immobilization by bonesetters had higher odds of amputation. Twenty-two percent of the cohort had a prolonged hospitalization, mostly for joint contractures, malunions, and infections. TBS with rigid immobilization was also associated with prolonged hospitalization.

To our knowledge, this is the first prospective, multicenter study of children presenting to hospitals after undergoing TBS. Other studies examining pediatric trauma and complications after TBS have reported a similar predominance of male patients^{1,6,14,23,24,27,31,36,42}, injuries after falls^{24,25,29,30,40}, and upper-extremity injuries^{31,32}. The mean household size and literacy rate in our cohort resembled national data for Ethiopia, for which a mean household size of 5.76 people⁹ and a literacy rate of 52%⁹ have been reported. Our cohort had a higher rate of poverty than the national reported rate of 24%⁹. This cohort represented 8 geographic regions, both rural and urban communities, the 3 largest Ethiopian religions, and households from diverse educational and socioeconomic backgrounds. Other studies of TBS in Ethiopia have included patients from Wolaita Sodo^{13,34}, Addis Ababa^{6,39,40}, Tigray¹⁴, Amhara³³, Oromia²⁵, and South Ethiopia Regional State²². Our findings corroborate evidence from Ethiopia, Ghana, Nigeria, and Tanzania that diverse populations patronize traditional bonesetters for various reasons^{8,20,27,36}. Approximately two-thirds of our cohort had parents or guardians who preferred TBS at the time of injury, and one-third still preferred TBS for future injuries. Similarly, other studies have demonstrated that 30% to 70% of their cohorts had a preference for TBS^{1,6}. This preference has been attributed to the accessibility, lower cost, and quicker service of TBS compared with formal medical services⁴. The popularity and prevalence of TBS in Ethiopia warrant consideration when planning trauma and orthopaedic service development³⁷.

We observed complications similar to those in other studies on TBS^{1,4}, including high rates of limb- and life-threatening complications^{6,22-24,32,38} such as missed compartment syndrome, limb ischemia, septicemia, and “bonesetter’s gangrene,” which has been attributed to excessively tight splints^{17,18,20,22-25,27,29-33}. Without a comparison to children who either did not receive TBS or who received TBS but did not present to a hospital, we could not

TABLE III Complications Observed Upon Presentation to a Study Site, Ordered by Decreasing Overall Frequency*

Complication Type	No. (%) of Patients		
	All (N = 460)	Amputation† (N = 26)	Prolonged Stay‡ (N = 102)
Any complication	361 (78.5)	26 (100.0)	92 (90.2)
All complications§			
Joint stiffness or contracture	232 (50.4)	7 (26.9)	51 (50.0)
Malunion	130 (28.3)	1 (3.8)	27 (26.5)
Muscle atrophy or weakness	87 (18.9)	2 (7.7)	19 (18.6)
Infected skin	57 (12.4)	16 (61.5)	28 (27.5)
Skin maceration or blistering	50 (10.9)	13 (50.0)	25 (24.5)
Chronic osteomyelitis	43 (9.3)	1 (3.8)	19 (18.6)
Chronic dislocation	33 (7.2)	–	9 (8.8)
Pressure sore	26 (5.7)	1 (3.8)	5 (4.9)
Neurovascular injury	25 (5.4)	12 (46.2)	9 (8.8)
Wet gangrene	22 (4.8)	22 (84.6)	14 (13.7)
Volkmann ischemic contracture#	20 (4.3)	1 (3.8)	5 (4.9)
Missed compartment syndrome#	19 (4.1)	6 (23.1)	7 (6.9)
Septicemia	19 (4.1)	8 (30.8)	12 (11.8)
Septic joint	12 (2.6)	1 (3.8)	7 (6.9)
Nonunion	11 (2.4)	–	1 (1.0)
Degloved wound	10 (2.2)	4 (15.4)	5 (4.9)
Delayed union	6 (1.3)	–	–
Dry gangrene	3 (0.7)	3 (11.5)	2 (2.0)
Osteonecrosis	2 (0.4)	–	–
Complex regional pain syndrome	2 (0.4)	–	1 (1.0)

*The 5 highest frequencies are highlighted in bold in each column (6 are highlighted in the Prolonged Stay column because muscle atrophy and chronic osteomyelitis were observed in equal numbers of patients). †Underwent a major limb amputation at a BOSAD study hospital. Amputations included shoulder disarticulation (n = 2) and above-elbow (n = 8), below-elbow (n = 6), above-knee (n = 4), and below-knee (n = 6) amputations. ‡Hospitalized at a BOSAD study hospital for >7 days. §Percentages do not sum to 100 due to patients having multiple complications. A total of 361 patients (78%) were recorded as having ≥1 complication. #Missed compartment syndrome refers to a late-presenting compartment syndrome with tissue damage but not yet having progressed to a Volkmann ischemic contracture.

definitively link TBS to severe complications in the general population. However, we found that, for children who underwent TBS and then presented to a hospital for further care, TBS with rigid splinting was associated with sixfold higher odds of amputation and twofold higher odds of prolonged hospitalization. Rigid splints that were placed tightly or after aggressive massage by bonesetters may have caused compartment syndrome and ischemia, and thus amputation^{22,23}. Rigid splints that crossed joints, held malreductions, or remained for prolonged periods may have caused contractures and malunions that required a prolonged hospitalization to treat^{8,23,32}. A TBS organic topical treatment was associated with fourfold higher odds of amputation in our cohort, perhaps due to nonsterile organic materials that were massaged into open wounds, exacerbating infections²⁰. Our findings corroborate the opinion among sub-Saharan African experts that certain TBS practices have a high risk of complications. Banning TBS or incorporating bonesetters into the formal trauma treatment and referral system in some capacity have both been proposed to prevent dangerous practices and poor outcomes^{2-4,17,18,28,35,37}.

Fracture displacement neither increased nor decreased the risk of either amputation or prolonged hospitalization. Compared with closed fractures, open fractures were not associated with significantly different odds of amputation, but non-osseous injuries were associated with sixfold higher odds of amputation. These non-osseous injuries might have been wounds or infections that were perhaps inadequately treated with or exacerbated by TBS. Children with open fractures of grade 2 or higher more often had prolonged hospitalizations. It has been well documented that open fractures have a higher rate of complications, regardless of exposure to TBS⁴³, although delays in formal treatment caused by TBS treatment may have increased the odds of complications requiring longer treatment in a hospital. Training bonesetters to recognize the risks of open fractures and infections, to eliminate risky practices such as rigid splinting and organic topical treatments, and to refer to health facilities appropriately could prevent amputations and prolonged hospitalizations.

Elbow and hip/thigh/knee injuries were associated with lower odds of amputation. Proximal lower-extremity injuries



Fig. 3

An 11-year-old boy with a proximal humeral fracture initially treated with TBS who presented to the hospital with missed compartment syndrome and gangrene requiring high-above-the-elbow amputation. The patient fell from ground level and was taken for TBS treatment 1 week after the injury. The TBS treatment included massage with application of herbal medicine and tight splinting of the arm and forearm. The patient presented to a BOSAD study hospital after 10 days of stay at a TBS practice with main symptoms of limb discoloration and diminished distal sensation. Radiographs showed a nondisplaced proximal humeral fracture. The limb was ischemic after a missed compartment syndrome, with gangrene and septicemia necessitating lifesaving emergency high-above-the-elbow amputation.

were perhaps harder to immobilize with tight splinting, reducing the risk of ischemia. However, the lower odds of amputation for elbow compared with other upper-extremity injuries was a puzzling finding that warrants further investigation. Presentation >28 days after injury was associated with significantly lower odds of amputation. It is possible that severe complications requiring amputation were obvious enough to prompt early hospital presentation or that children with severe complications died before hospital arrival if >28 days had passed since the injury. Rural residence independently increased the odds of amputation 6.7-fold. TBS methods may differ between rural and urban settings on the basis of bonesetters' knowledge, practice of sterile technique, and proximity to health facilities for referral. Children from rural communities therefore represent an especially vulnerable population requiring targeted efforts to reduce TBS-associated complications. Such efforts may include orthopaedic capacity-building in rural areas, educational programs, public campaigns, and outreach to rural bonesetters and community members.

Older children had higher odds of prolonged hospitalization, perhaps due to a reduced potential for bone remodeling and recovery of joint motion without surgery⁴⁴. Children from Oromia and SNNPR also demonstrated higher odds of prolonged hospitalization compared with those from the Amhara, Sidama, and Somali regions. This could represent regional differences in TBS treatment methods or in clinical practices at

the enrolling BOSAD centers, which warrants further investigation. Children from households with higher education levels had lower odds of prolonged hospitalization, an effect that persisted after controlling for poverty status. Education has been associated with improved health literacy and health outcomes^{19,45,46}. Poverty was associated with both amputation and prolonged hospitalization in the bivariate analyses but lost significance in the multivariable model, likely because it was accounted for by covariates such as rural or urban residence and highest household education level.

A preference for TBS and a visit to a health facility prior to TBS did not affect the odds of either amputation or prolonged hospitalization. Although treatment details were unavailable, our findings suggest that prior visits to a health facility did not meaningfully alter patients' outcomes. Patients reportedly abscond from hospitals for reasons such as fear of surgery, amputation, or hospital costs; greater faith in TBS; pressure from family and friends^{1,4,8,17,18,20,27,36}; and prior negative experiences in hospitals²⁷. Given that 19% of the children in our cohort visited a health facility before undergoing TBS, the complications associated with TBS could be reduced by training health-care providers in evidence-based trauma care, identifying patients who are at risk for poor outcomes, and engendering patient trust. Improving the availability and quality of orthopaedic services in Ethiopia

TABLE IV Bivariate and Multivariable Predictors of Amputation in Logistic Regression Analyses

Variable	Rate of Amputation*	Bivariate†		Multivariable§		Parsimonious Model#	
		OR (95% CI)	P Value†	AOR (95% CI)	P Value‡	AOR (95% CI)	P Value‡
Age group			0.511				
0 to 5 years**	3.3 (3/90)	1					
6 to 10 years	5.7 (13/227)	1.76 (0.49, 6.34)					
11 to 17 years	7.0 (10/143)	2.18 (0.58, 8.15)					
Sex			0.521				
Male**	5.2 (18/343)	1					
Female	6.8 (8/117)	1.33 (0.56, 3.13)					
Highest household education level			0.484				
No education**	6.2 (4/65)	1					
Primary school	5.2 (4/77)	0.84 (0.20, 3.48)					
Secondary school or higher	3.6 (4/111)	0.57 (0.14, 2.36)					
Informal††	10.7 (6/56)	1.83 (0.49, 6.85)					
Unknown	5.3 (8/151)	0.85 (0.25, 2.94)					
Poverty status			0.018††		0.255		
Above poverty line**	1.4 (2/144)	1		1			
Below poverty line	7.6 (24/316)	5.84 (1.36, 25.04)		2.90 (0.46, 18.06)			
Residence type			<0.001††		0.004††		0.002††
Urban**	1.7 (4/242)	1		1		1	
Rural	10.1 (22/218)	6.68 (2.26, 19.70)		8.80 (1.97, 39.34)		6.71 (2.01, 22.41)	
Region			0.383				
Oromia§§ **	8.0 (15/188)	1					
Amhara##	5.8 (5/86)	0.71 (0.25, 2.03)					
Sidama	1.7 (1/60)	0.20 (0.03, 1.51)					
SNNPR	4.9 (4/82)	0.59 (0.19, 1.84)					
Somali***	2.3 (1/44)	0.27 (0.03, 2.09)					
Injury mechanism			0.419				
Fall from ground level**	3.5 (6/171)	1					
Fall from height	7.2 (13/181)	2.13 (0.79, 5.73)					
Interpersonal violence	3.3 (1/30)	0.95 (0.11, 8.17)					
Road traffic incident	4.0 (1/25)	1.15 (0.13, 9.93)					
Other	9.4 (5/53)	2.86 (0.84, 9.80)					
Injured body part†††			0.024††		0.012††		0.015††
Elbow**	1.0 (2/194)	1		1		1	
Shoulder/arm	11.8 (4/34)	12.80 (2.25, 72.96)		42.41 (4.42, 407.38)		22.56 (3.03, 167.88)	
Forearm/wrist/hand	10.9 (11/101)	11.73 (2.55, 54.04)		26.78 (3.71, 193.39)		13.80 (2.59, 73.62)	
Hip/thigh/knee	5.3 (3/57)	5.33 (0.87, 32.74)		13.48 (1.38, 131.54)		4.30 (0.61, 30.25)	
Leg/ankle/foot	8.1 (6/74)	8.47 (1.67, 42.98)		9.91 (1.34, 73.43)		6.52 (1.08, 39.15)	
Injury type			0.178		0.002††		0.060
Closed fracture and/or dislocation**	4.4 (16/364)	1		1		1	
Open fracture, grade 1	10.0 (1/10)	2.42 (0.29, 20.25)		1.08 (0.06, 18.31)		0.97 (0.07, 14.37)	
Open fracture, grade ≥2	11.8 (2/17)	2.90 (0.61, 13.78)		0.83 (0.14, 4.88)		0.75 (0.14, 4.12)	
Non-osseous injury	10.1 (7/69)	2.46 (0.97, 6.21)		22.77 (4.39, 118.07)		5.76 (1.56, 21.28)	
Fracture displacement			0.403				
No**	6.8 (5/74)	1					
Yes	4.4 (14/317)	0.64 (0.22, 1.83)					

continued

TABLE IV (continued)

Variable	Rate of Amputation*	Bivariate†		Multivariable§		Parsimonious Model#	
		OR (95% CI)	P Value†	AOR (95% CI)	P Value†	AOR (95% CI)	P Value†
Time to presentation			0.005††		<0.001††		<0.001††
0-14 days**	9.2 (13/142)	1		1		1	
15-28 days	10.3 (9/87)	1.14 (0.47, 2.80)		1.21 (0.39, 3.82)		1.28 (0.44, 3.73)	
>28 days	1.7 (4/231)	0.17 (0.06, 0.55)		0.04 (0.01, 0.18)		0.08 (0.02, 0.29)	
TBS was first choice			0.156				
No**	3.6 (6/167)	1					
Yes	6.8 (20/293)	1.97 (0.77, 5.00)					
Visited health facility before TBS			0.988				
No**	5.7 (21/371)	1					
Yes	5.6 (5/89)	0.99 (0.36, 2.71)					
Prefers TBS for future injury			0.985				
No**	5.7 (17/300)	1					
Yes	5.6 (9/160)	0.99 (0.43, 2.28)					
TBS topical treatment			0.004††		0.022††		0.009††
None**	4.3 (8/188)	1		1		1	
Organic‡‡‡	13.4 (11/82)	2.89 (1.47, 5.70)		5.43 (1.56, 18.87)		3.88 (1.40, 10.73)	
Inorganic§§§	3.7 (7/190)	1.16 (0.61, 2.19)		1.51 (0.41, 5.58)		1###	
TBS immobilization			0.011††		0.002††		0.004††
None**	0.9 (1/112)	1		1		1	
Rigid****	10.2 (17/166)	12.66 (1.66, 96.59)		158.15 (9.55, 2617.79)		5.84 (1.74, 19.60)	
Soft††††	4.4 (8/182)	5.10 (0.63, 41.36)		52.40 (3.68, 746.21)		1###	

*Values are given as the percentage of patients who had an amputation, with the numerator and denominator in parentheses. †Bivariate analysis was performed for each covariate, with amputation as the outcome measure. ‡Type-III p values are shown for categorical variables. §The multivariable model included categories with p < 0.10 in the bivariate screening. #The parsimonious model was constructed by including all variables that were significant or nearly so (p < 0.10) in the multivariable model. **Reference group. ††Ability to read and write but did not attend formal grade school. ‡‡Significant. §§The Oromia region category includes 18 patients from the nearby Harari region. ##The Amhara region category includes 1 patient from the nearby Benishangul-Gumuz region. ***The Somali region category includes 3 patients from the nearby city Dire Dawa. †††Body part categories were condensed to address small sample sizes. ‡‡‡Organic topical materials that had been applied included mud, leaves or other plant materials, and butter. §§§Inorganic materials included petroleum jelly or another chemical or drug. ###Categories were combined in the analysis due to similar ORs and/or low counts in the categories. ****Rigid immobilization included the use of bamboo, wooden, or metal splints. ††††Other non-rigid immobilizations included wrapping with a towel, leather splint, or some other soft dressing.

may represent the best strategy for reducing TBS patronage and TBS-associated complications³⁷.

This study had limitations. First, injury characteristics, TBS treatment methods, and complications were assessed at study enrollment and were thus subject to recall bias and subjectivity. Second, we had no control group by which to compare demographics, injury characteristics, and complications between children who did and did not receive TBS. Establishing such a control group by enrolling all children treated at each BOSAD center regardless of TBS patronage was beyond the means of our Ethiopian study setting. Future investigations should aim to compare complication rates between children who did and did not undergo TBS. Third, because we enrolled patients at hospitals, children who never sought hospital care after TBS were excluded, leading to sampling bias. We enrolled all children who had undergone TBS, regardless of complication status, but our sampling method may have magnified the observed complication rate. Conversely, children without the means to present to a health facility may have been excluded, possibly decreasing the observed complication rate. The BOSAD

Study included a community-based assessment, which we hope will clarify the true complication rate after TBS in a future publication.

Despite these limitations, this was the largest, most comprehensive investigation to date of children presenting to a hospital after undergoing TBS, and the valuable insights that it provides regarding high-risk populations, injuries, and TBS treatment practices will guide future interventions aimed at preventing poor outcomes. We found that children in Ethiopia who underwent TBS and then presented to hospital had a 6% amputation rate and a 22% rate of prolonged hospitalization. Amputation was associated with rigid splinting and organic topical treatments by bonesetters, and rigid splinting was also associated with prolonged hospitalization. These outcomes may be prevented by training bonesetters to avoid these practices, to recognize severe injuries, and to promptly refer patients to health facilities. These interventions could be facilitated through government registration of bonesetters, with a defined code of conduct and a monitored scope of practice. Improving the quality, accessibility, and affordability of trauma care in Ethiopia, especially in rural areas,

TABLE V Bivariate and Multivariable Predictors of Prolonged Hospitalization in Logistic Regression Analyses

Variable	Rate of Prolonged Hospitalization*	Bivariate†		Multivariable§		Parsimonious Model#	
		OR (95% CI)	P Value†	AOR (95% CI)	P Value†	AOR (95% CI)	P Value†
Age group			0.010**		0.116		0.062
0 to 5 years††	12.2 (11/90)	1		1		1	
6 to 10 years	21.6 (49/227)	1.98 (0.98, 4.00)		1.67 (0.76, 3.68)		1.82 (0.84, 3.96)	
11 to 17 years	29.4 (42/143)	2.99 (1.44, 6.17)		2.49 (1.04, 5.99)		2.77 (1.18, 6.50)	
Sex			0.617				
Male††	22.7 (78/343)	1					
Female	20.5 (24/117)	0.88 (0.52, 1.47)					
Highest household education level			<0.001**		<0.001**		<0.001**
No education††	27.7 (18/65)	1		1		1	
Primary school	32.5 (25/77)	1.26 (0.61, 2.59)		0.63 (0.24, 1.63)		1††	
Secondary school or higher	15.3 (17/111)	0.47 (0.22, 1.00)		0.33 (0.12, 0.89)		0.40 (0.21, 0.79)	
Informal§§	35.7 (20/56)	1.45 (0.67, 3.14)		1.10 (0.41, 2.94)		1††	
Unknown	14.6 (22/151)	0.45 (0.22, 0.90)		0.20 (0.07, 0.53)		0.24 (0.12, 0.48)	
Poverty status			<0.001**		0.781		
Above poverty line††	12.5 (18/144)	1		1			
Below poverty line	26.6 (84/316)	2.53 (1.46, 4.41)		1.10 (0.55, 2.21)			
Residence type			0.017**		0.937		
Urban††	17.8 (43/242)	1		1			
Rural	27.1 (59/218)	1.72 (1.10, 2.68)		0.98 (0.53, 1.80)			
Region			0.002**		0.003**		0.001**
Oromia†† ##	25.0 (47/188)	1		1		1	
Amhara***	19.8 (17/86)	0.74 (0.40, 1.38)		0.31 (0.13, 0.75)		0.36 (0.16, 0.81)	
Sidama	13.3 (8/60)	0.46 (0.20, 1.04)		0.40 (0.14, 1.10)		0.36 (0.14, 0.93)	
SNNPR	35.4 (29/82)	1.64 (0.94, 2.87)		0.95 (0.46, 1.96)		1.05 (0.53, 2.09)	
Somali†††	2.3 (1/44)	0.07 (0.01, 0.52)		0.03 (0.00, 0.28)		0.03 (0.00, 0.29)	
Injury mechanism			0.881				
Fall from ground level††	21.1 (36/171)	1					
Fall from height	23.8 (43/181)	1.17 (0.71, 1.93)					
Interpersonal violence	20.0 (6/30)	0.94 (0.36, 2.47)					
Road traffic incident	16.0 (4/25)	0.71 (0.23, 2.21)					
Other	24.5 (13/53)	1.22 (0.59, 2.52)					
Injured body part†††			0.053		0.353		0.315
Elbow††	18.6 (36/194)	1		1		1	
Shoulder/arm	26.5 (9/34)	0.66 (0.27, 1.63)		1.98 (0.74, 5.29)		2.06 (0.79, 5.37)	
Forearm/wrist/hand	19.8 (20/101)	0.42 (0.23, 0.77)		1.03 (0.51, 2.12)		1.07 (0.52, 2.17)	
Hip/thigh/knee	19.3 (11/57)	0.46 (0.23, 0.90)		1.02 (0.41, 2.56)		1.09 (0.45, 2.65)	
Leg/ankle/foot	35.1 (26/74)	0.44 (0.20, 1.00)		1.88 (0.88, 4.03)		1.93 (0.91, 4.07)	
Injury type			0.007**		0.175		0.104
Closed fracture††	20.1 (73/364)	1		1		1	
Open fracture, grade 1	30.0 (3/10)	1.71 (0.43, 6.77)		1.46 (0.26, 8.17)		1.76 (0.33, 9.26)	
Open fracture, grade ≥2	58.8 (10/17)	5.69 (2.10, 15.47)		4.16 (1.17, 14.70)		4.52 (1.33, 15.28)	
Non-osseous injury	23.2 (16/69)	1.20 (0.65, 2.23)		1.11 (0.52, 2.35)		1.10 (0.52, 2.32)	
Fracture displacement			0.185				
No††	16.2 (12/74)	1					
Yes	23.3 (74/317)	1.57 (0.80, 3.08)					

continued

TABLE V (continued)

Variable	Rate of Prolonged Hospitalization*	Bivariate†		Multivariable§		Parsimonious Model#	
		OR (95% CI)	P Value†	AOR (95% CI)	P Value†	AOR (95% CI)	P Value†
Time to presentation			0.039**		0.085		0.076
0-14 days††	26.1 (37/142)	1		1		1	
15-28 days	28.7 (25/87)	1.14 (0.63, 2.08)		1.24 (0.61, 2.52)		1.29 (0.65, 2.55)	
>28 days	17.3 (40/231)	0.59 (0.36, 0.99)		0.61 (0.33, 1.13)		0.62 (0.34, 1.13)	
TBS was first choice			0.037**		0.720		
No††	27.5 (46/167)	1		1			
Yes	19.1 (56/293)	0.62 (0.40, 0.97)		0.90 (0.52, 1.57)			
Visited health facility before TBS			0.020**		0.246		
No††	19.9 (74/371)	1		1			
Yes	31.5 (28/89)	1.84 (1.10, 3.08)		1.47 (0.77, 2.82)			
Prefers TBS for future injury			0.198				
No††	24.0 (72/300)	1					
Yes	18.8 (30/160)	0.73 (0.45, 1.18)					
TBS topical treatment			0.004**		0.482		0.480
None††	17.0 (32/188)	1		1		1	
Organic§§§	29.3 (24/82)	2.89 (1.47, 5.70)		1.60 (0.74, 3.44)		1.59 (0.74, 3.39)	
Inorganic###	24.2 (46/190)	1.16 (0.61, 2.19)		1.19 (0.62, 2.28)		1.15 (0.61, 2.17)	
TBS immobilization			0.043**		0.077		0.125
None††	16.1 (18/112)	1		1		1	
Rigid****	28.3 (47/166)	2.06 (1.12, 3.78)		2.45 (1.11, 5.40)		2.20 (1.02, 4.73)	
Soft††††	20.3 (37/182)	1.33 (0.72, 2.48)		2.08 (0.97, 4.44)		1.82 (0.88, 3.76)	

*Values are given as the percentage of patients who had a prolonged hospitalization (>7 days), with the numerator and denominator in parentheses. †Bivariate analysis was performed for each covariate, with prolonged hospitalization as the outcome measure. ‡Type-III p values are shown for categorical variables. §The multivariable model included categories with $p < 0.1$ in the bivariate screening. #The parsimonious model was constructed by including all variables that were significant or nearly so ($p < 0.10$) in the multivariable model. "Time to presentation" was considered a clinically important predictor and likely modifier of other included variables and was therefore also included in the final parsimonious model. **Significant. ††Reference group. ‡‡Categories combined in the analysis due to similar ORs and/or low counts in the categories. §§Ability to read and write but did not attend formal grade school. ##The Oromia region category includes 18 patients from the nearby Harari region. ***The Amhara region category includes 1 patient from the nearby Benishangul-Gumuz region. †††The Somali region category includes 3 patients from the nearby city Dire Dawa. ††††Body part categories were condensed to address small sample sizes. §§§Organic topical materials that had been applied included mud, leaves or other plant materials, and butter. ###Inorganic materials included petroleum jelly or another chemical or drug. ****Rigid immobilization included the use of bamboo, wooden, or metal splints. ††††Other non-rigid immobilizations included wrapping with a towel, leather splint, or some other soft dressing.

could reduce TBS-associated complications by fostering trust in formal medical services and reducing TBS patronage. We hope that our findings will inform a scope of practice for bonesetters and shape policy interventions to reduce TBS-associated complications among vulnerable children, especially in rural Ethiopia.

Appendix

 Supporting material provided by the authors is posted with the online version of this article as a data supplement at [jbjs.org \(http://links.lww.com/JBJS/I419\)](http://links.lww.com/JBJS/I419). ■

Ephrem G. Adem, MD¹
Papa K. Morgan-Asiedu, MD, MPH^{2,3}
Mengistu G. Mengesha, MD¹
Mario Keko, DrPH, MPH⁴

Chen Mo, DrPH⁴
Sintayehu Bussa, MD¹
Eden Alemu, MSc¹
Yishak Zerihun, MD¹
Habtamu T. Derilo, MD⁵
Mahamed Areis, MD⁶
Kaleab T. Reda, MD⁷
Wubshet A. Workneh, MD⁸
Bahru A. Shiferaw, MD⁸
Moa C. Jira, MD⁹
Habtamu B. Gula, MD¹⁰
Mulugeta B. Geneti, MD¹¹
Claude Martin Jr., MD, MBA¹²
Kiran J. Agarwal-Harding, MD, MPH^{2,4}
William J. Harrison, MD¹²

¹Department of Orthopedic Surgery, Hawassa University Comprehensive Specialized Hospital, Hawassa, Ethiopia

²Harvard Global Orthopaedics Collaborative, Boston, Massachusetts

³Perelman School of Medicine, University of Pennsylvania, Philadelphia, Pennsylvania

⁴Department of Orthopaedic Surgery, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, Massachusetts

⁵Department of Orthopedic Surgery, Wachemo University Hospital, Hosaena, Ethiopia

⁶Department of Orthopedic Surgery, Jigjiga University Hospital, Jigjiga, Ethiopia

⁷Department of Orthopedic Surgery, University of Gondar Specialized Hospital, Gondar, Ethiopia

⁸Department of Orthopedic Surgery, Bahir Dar University Hospital, Bahir Dar, Ethiopia

⁹Department of Orthopedic Surgery, Haramaya General Hospital, Haramaya, Ethiopia

¹⁰Department of Orthopedic Surgery, Assela University Hospital, Ethiopia

¹¹Department of Orthopedic Surgery, Jimma University Medical Center, Ethiopia

¹²AO Alliance Foundation, Davos, Switzerland

Email for corresponding author: kahardin@bidmc.harvard.edu

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