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RESEARCH ARTICLE

An Evaluation of the use of External Fixator in the Management of Open Tibial Shaft Fractures at a Tertiary Hospital in Pretoria, South Africa

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Abstract:

Background:

Lower limb fractures result in a greater physical impact on health than those in other parts of the body. Open tibial fractures are orthopaedic emergencies necessitating prompt treatment. A study was conducted to determine the clinical profiles and outcomes of patients treated for open tibial fractures using the external fixator method.

Methods:

We conducted a retrospective cohort study on 101 patients who had been treated with the external fixator method for open tibial fractures from 1st January, 2014 to 31st December, 2015. Patient profiles included their baseline characteristics, risk factors, and injury mode. Clinical outcomes were sepsis, delayed union, and the number of days to the union. Correlation tests were conducted to establish associations. All statistical tests were performed on SAS, Release 9.3 (2015). Statistical significance was set at $p \leq 0.05$.

Results:

Most respondents were male (87; 86.1%) with a secondary level of education (83; 82.2%). The most frequent modes of injury were motor-vehicle accidents (MVAs) (34; 33.7%) and assault (21; 20.8%). MVA (27; 26.7%) resulted in the highest complications. Osteomyelitis and pin traction sepsis accounted for 19/65 (29%) of all complications. Delayed union was mostly observed among respondents who smoked cigarettes, *i.e.*, 49/63 (29%).

Conclusion:

MVA, PVA, gunshot, and assault constituted the highest proportions. Cigarette smoking was the risk factor with the highest proportion and was related to delayed union and non-union. Osteomyelitis and pin tract sepsis occurred in high proportions. Behavioural change towards quitting smoking and antibiotic coverage should be advocated to benefit patients with open tibial fractures.

Keywords: Open tibial fractures, External fixator, Gustilo-Anderson classification, Risk factors, Complications, Fracture site.

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1. INTRODUCTION

Fractures of the tibial shaft are the most common long bone fractures and are seen in 4% of the adult population [1]. A systematic review has reported that lower limb fractures are associated with a greater physical impact on health compared to those in other parts of the body [2]. Open tibial shaft fractures are regarded as orthopaedic emergencies [3], which, if not treated promptly, can result in unwanted complications, which include sepsis and amputations [4 - 6]. There is evidence from a study conducted in South India on patients selected according to the Gustillo-Anderson classification that external fixators could be the method of choice for fixing open tibial fractures in a simple, economical, and effective way [7].

Studies conducted in various settings indicate a wide variation in the period of time it takes for patients to attain bone healing following tibial fractures. A prospective review of 19 patients conducted at the Nepal Medical College indicated that 17 patients healed over a period of 77- 343 days, and two

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required bone transport following treatment with an external fixator, giving them a success rate of 89.5% over 343 days [8]. In another study, in a rural setting in India, 42 patients were retrospectively reviewed, and the average time to healing of these patients was 166 days in Gustilo-Anderson III (GA III), with an average of 121 days in both Gustilo-Anderson I (GA I) and Gustilo-Anderson II (GA II) [9]. In another study conducted in Egypt on 34 patients, healing was satisfactory in GA I and GA II fractures, with an average time to union of 133 days and an infection rate of 7% [10]. In a study by Stojković, 14 fractures were treated with an external fixator, with the union rate recorded as 83.68% and an average fracture healing time of 124 days. Non-union was evident in four patients, and the mal-union rate was 4.08% [11], while Piwani *et al*. recorded a union time of 126-196 days among 30 patients [12].

Regarding the mode of injuries, injuries to the lateral part of the tibia occur most commonly and occur consequent to a direct force to the lateral aspect of the knee, while injuries to the medial tibial aspect are sustained from high-energy mechanisms as they require more force, including falling from a height and landing on the feet, motor vehicle accidents, and other sources of direct trauma [13]. Tibial fractures, as a result of low-energy mechanisms, occur mostly in the elderly or other populations with osteoporotic diseases [13]. The incidence of violence in South Africa is topical worldwide [14], resulting in tibial fractures through gunshots and assault.

Regarding complications, open tibia fractures have been found to be associated with an increased risk of infection, delayed union, non-union, and wound complications [15]. They are often associated with severe bone and soft-tissue injury with an increased risk of infection when there is fracture site contamination and devitalization of the surrounding soft tissue. It has been recommended that the management of open tibial shaft fractures should begin with an assessment of the bone and soft tissue surrounding the tibial injury. This should be followed by the classification of these injuries according to the Gustilo-Anderson system at the time of surgical debridement [16]. The classification is useful in guiding treatment and predicting clinical outcomes. Prompt administration of antibiotic prophylaxis after injury, thorough debridement, irrigation, and bony stabilization have been found to minimize the risk of infection and improve clinical outcomes [16]. It has been suggested that severe open tibial fractures should be referred directly to specialist centres for simultaneous combined management by orthopaedic and plastic surgeons to minimize complications [17].

Risk factors for the development of complications have been listed in the literature. The male gender, immunosuppression, smoking, lower extremity fractures, and GA III are significant risk factors for the development of infectious complications and non-union [18, 19].

However, there was a scarcity of studies conducted on the external fixation of open tibial shaft fractures in South Africa. One study was conducted at Stellenbosch University in Bloemfontein in 2008, in which the researchers recommended wound irrigation with a copious amount of water for all wounds. The recommendation for smaller wounds was debridement and skin suture followed by a cast, while for bigger wounds (GA II and above), irrigation, debridement, and application of an external fixator, followed by a repeat debridement after 48 hours, were recommended. These were found to yield good results [20].

Dr. George Mukhari Academic Hospital (DGMAH) is a tertiary hospital. At the time of the study, the hospital frequently received patients with open tibial fractures who were referred late to the hospital. Sometimes, the delay occurred within the hospital when the theatre was not readily available for prompt debridement and application of an external fixator. It was observed in the department of orthopaedic surgery that patients who presented with open tibial shaft fractures tended to develop sepsis, which became more difficult to manage once it had set in, as reported in other studies as well [21, 22]. When a patient was admitted with an open tibial shaft fracture, she/he was assessed for severity of the injury (size of the wound, comminution, contamination, and vascular involvement), followed by the Gustilo-Anderson classification as Grade I, II, IIIa, IIIb or IIIc according to its severity [23, 24]. Since all open fractures should be regarded as orthopaedic emergencies [3], the patient must be taken to theatre for urgent debridement and external fixation after receiving anti-tetanus toxoid and pre-operative antibiotics, followed by another dose of antibiotics post-operatively. It is known from the literature that a delay in the treatment lasting for more than 24 hours aggravates the tibial fracture state, relegating the patient to a more advanced Gustilo-Anderson classification [4 - 6].

This study aimed to evaluate the outcomes of patients treated with an external fixator for open tibial shaft fractures at DGMAH, raise awareness among the referring orthopaedic surgeons of the importance of prompt treatment of these fractures, and minimise the risk of complications at the Tshwane District in Pretoria.

2. MATERIALS AND METHODS

2.1. Study Design

We conducted a retrospective cohort study to determine the clinical outcome of patients who had undergone the external fixator method in the management of their open tibial shaft fractures at DGMAH.

2.2. Study Population and Sampling Procedure

DGMAH is a 1 650-bed, multidisciplinary tertiary hospital situated about 30km north of Pretoria in the Gauteng province of South Africa. It is associated with the Sefako Makgatho Health Sciences University and caters to mainly black African patients. At the time of the study, 240 beds were allocated to the Department of Orthopaedics for inpatients, with the outpatient unit serving about 80 patients per day, twice a week for both male and female units.

Files of all patients who had been admitted to the hospital with open tibial shaft fracture 18 years old and above from 1st January, 2014 to 31st December, 2015 were eligible for inclusion in the study. We included all files of the patients who had sustained open tibial fractures involving the tibial shaft: proximal, middle, or distal third. We evaluated fracture union radiographically. Non-union is defined as when less than three out of four cortices have bridging callus in anteroposterior and

lateral views 365 days and beyond after the initial surgery [25]. Delayed union is defined as failure of union 90 days after the initial surgery [26, 27]. Files with missing data with respect to the required variables were excluded from the study.

We excluded patients who had simultaneously sustained other injuries other than tibial fractures on presentation, those with tibial bone deformities, closed and/or comminuted tibial fractures, intra-articular tibial fractures, tibial fractures that required vascular repair, and all pathological tibial fractures. According to the departmental records, an average of 60 patients per annum presented with the condition of interest for the study. Accordingly, we sampled 101 patient files out of the 133 which were eligible for inclusion. At the time of the study in 2018, we noted the final outcome of the surgical procedure for each of the 101 patients as recorded in the file.

2.3. Data Collection

The study variables were inserted on a spreadsheet, including patient age, gender, date of injury, mode of injury, fracture site, complications (*e.g*., sepsis), and the average time to healing. Furthermore, we collected data on the mode of injury, such as pedestrian-vehicle accident (PVA), motor vehicle accident (MVA), assault, falling, and gunshot. Patients had been followed up in the hospital orthopaedic clinic until fracture union occurred or for a maximum period of one year (365 days). The study outcomes were pin-tract sepsis, non-union, delayed union, septic wound, osteomyelitis, and malunion. Data were collected regarding the mode of injury *versus* complications and the number of days to union *versus* risk factors (smoking, immune suppression, substance abuse).

2.4. Data Analysis

Continuous variables were presented as means, minimum and maximum values, and categorical variables as frequencies and proportions. The chi-square test was used to compare group variables. All statistical procedures were performed on SAS 9.3 TS1M2 (2012). Statistical significance was set at a p-value < 0.05. The results are presented in Tables.

3. RESULTS

Table **1** indicates that the majority of the respondents were male (87; 86.1%), single (72 (71.3%), and unemployed (56; 55.4%) with a secondary level of education (83; 82.2%).

Table **2** indicates that the most frequent mode of injury was motor-vehicle accidents (MVAs) (34; 33.7%), followed by assault (21; 20.8%), and an equal proportion of pedestrian-vehicle accidents (PVAs) and gunshots (20; 19.8).

Table **3** demonstrates the proportions of the mode of injury within each sex (male or female), and it can be noted that, among the males, 30/97 (34.5%) of the injuries were attributable to MVA, comparable to 4/14 (28.6%) among the females. PVA, assault, and gunshots contribute to 17/87 (19.5%) each, also comparable to about 3/14 (21.4%) among females. There was no statistically significant association between the mode of injury and sex ($p = 0.938$). It is also noted that more than half of the patients (54/101; 53.5%), combining both sexes, sustained open tibial fractures due to motor-vehicle-related injuries (MVA and PVA).

Table 1. Baseline characteristics (n = 101).

Variable	-
Male	87 (86.1%)
Female	14 (13.9%)
Mean age	36.2
Age range	19–68
Marital Status	-
Single	72 (71.3)
Married	29 (28.7)
Employment Status	-
Employed	43 (42.6)
Unemployed	56 (55.4)
Pensioner	2 (2.0)
Highest Level of Education	-
None	8 (7.9)
Primary	9 (8.9)
Secondary	83 (82.2
Tertiary	1 (1.0)

Table 2. Mode of injury (n = 101).

Mode of Injury	Frequency n (%)
PVA	20 (19.8)
MVA	34 (33.7)
Assault	21 (20.8)
Falling	5 (5.0)
Gunshot	20 (19.8)
Not reported	1 (0.99)
Total	101 (100.0

Abbreviations: PVA: pedestrian-vehicle accident. MVA: motor-vehicle accidents.

Table **4** illustrates that 65 (64.4%) patients developed complications. The mode of injury that resulted in the highest complications was MVA (27; 26.7%). This was followed by PVA and assault in equal proportions (12; 11.9%) and gunshots (11; 10.9%). Of the complications that followed MVAs, pin traction sepsis and osteomyelitis accounted for 19/65 (29%) of all the complications. Assault and gunshot injuries accounted for 23/65 (35.4%) of all complications. Osteomyelitis was the complication with the highest proportion among all the patients presenting with open tibial fractures, *i.e*., 28 (27.7%). However, there was no statistical difference among the complications in relation to the mode of injury ($p = 0.09$).

Table **5** illustrates that, of the 101 patients who were evaluated for the number of days to the bone union, 32 (32.0%) had no risk factors, 63 (62.4%) admitted to cigarette smoking, 4 (4.0%) were immunosuppressed, and 2 (2.0%) used illicit drugs (substance abuse). Out of the 63 patients who smoked cigarettes, 49 (77.8%) attained union over 101 – 180 days (delayed union), while 10 (15.9%) had delayed union, which warranted intervention to achieve union. However, there was no significant association between the number of days to union and risk factors ($p = 0.98$).

Table 3. Mode of injury by sex (n = 101).

Mode of Injury	Sex n (%)		-
-	Male	Female	p-value
PVA	17 (19.5)	3 (21.4)	0.938
MVA	30 (34.5)	4 (28.6)	
Assault	17 (19.5)	4 (28.6)	
Falling	5 (5.8)	0 (0.0)	
Gunshot	17 (19.5)	3 (21.4)	
Not reported	1 (1.2)	0 (0.0)	
Total	87 (86.1)	14 (13.9)	

Abbreviations: PVA: pedestrian-vehicle accident; MVA: motor vehicle accident

Table 4. Complications by mode of injury (n=101).

Mode of Injury	Complications n(%)								Grand Total	-
n (%)	Nil	Pin Tract Sepsis	Non-union	Delayed Union	Septic Wound	Osteomyelitis	Mal-union	Total Complications		p-value
PVA	8 (7.9)	3 (3.0)	1 (1.0)	0 (0.0)	1 (1.0)	6 (5.9)	1 (1.0)	12 (11.9)	20 (19.8)	
MVA	7 (6.9)	9 (8.9)	4 (4.0)	3 (3.0)	0 (0.0)	10 (9.9)	1 (1.0)	27 (26.7)	34 (33.7)	
Assault	9 (8.9)	4 (4.0)	0 (0.0)	1 (1.0)	1 (1.0)	6 (5.9)	0 (0.0)	12 (11.9)	21 (20.8)	
Falling	2 (2.0)	1 (1.0)	0 (0.0)	1 (1.0)	0 (0.0)	1 (1.0)	0 (0.0)	3 (3.0)	5 (5.0)	0.09
Gunshot	9 (8.9)	2 (2.0)	0 (0.0)	4 (4.0)	0 (0.0)	5 (5.0)	0 (0.0)	11 (10.9)	20 (19.8)	
Unreported	1 (1.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.0)	
Total	36 (35.6)	19 (18.8)	5 (5.0)	9 (8.9)	2 (2.0)	28 (27.7)	2 (2.0)	65 (64.4)	101 (100.0)	

Table 5. Number of days to union *versus* risk factors (n = 101).

Number of Days to Union	Risk Factor				-	p-value
Number of Days	None	Smoking	Immuno-suppressed	Substance Abuse	Total	
< 80	1	0	0	0	1	
80 – 100	4	4	0	0	8	
101 – 120	11	20	2	0	33	
121 – 140	6	15	1	1	23	
141 – 160	6	9	0	0	15	0.98
161 – 180	3	5	1	1	10	
181 – 200	0	6	0	0	6	
201 – 220	0	1	0	0	1	
221 – 240	1	2	0	0	3	
>240	0	1	0	0	1	
Total	32	63	4	2	101	

4. DISCUSSION

This study aimed at determining the clinical profiles and outcomes of patients who had undergone the external fixator method in the management of their open tibial shaft fractures. The study demonstrated that most of the patients were male. The modes of injury of most patients were MVA, PVA, gunshot, and assault. Cigarette smoking was the risk factor found in the majority of the patients and was related to a high proportion of delayed union and non-union of the open tibial fractures, while osteomyelitis and pin tract infection constituted the complications with the highest proportion of occurrence.

The majority of the respondents (86%) were male. The high proportion of males in comparison to females sustaining open tibial fractures has been reported in a number of studies [1, 9, 10]. In the current study, a high proportion of open tibial fractures occurred among those with a secondary level of education (82%), contrary to the study conducted in Tanzania, where the highest proportion was among patients with primary education (60%) and only 25% among patients with secondary education [28]. The current study also indicated that the highest proportion of tibial injuries was through MVA (34%). Further studies are required to establish if any relationship exists between the level of education, which enables individuals to acquire motor vehicles, and possibly the higher risk of trauma through MVAs, compared to those with lower levels of

education in the South African context.

In this study, the highest mode of injury was MVA, followed by PVA, gunshots, and assault, with no significant differences between the male and female sexes. Similar frequencies have been reported in other studies [29, 30]. However, more than half of the patients (54%), inclusive of both sexes, sustained open tibial fractures as a result of motor-vehicle-related injuries (MVA and PVA). Almost one in three (34%) of the complications resulted from MVAs, while more than a quarter (27%) of patients who developed complications had sustained the injury through MVAs. This could be related to the high incidence of road traffic crushes associated with high-risk behaviour (including drunken driving and alcohol use by pedestrians) in South Africa [31].

The delayed union has been defined as the failure of a union at the expected time (three to four months for lower limbs) [26, 27]. Our study has demonstrated that cigarette smoking was the risk factor, with the highest proportion of patients who developed delayed union (78%) and non-union (16%). This has already been observed in another study, where smoking in the perioperative period resulted in the highest percentage (3.0%) compared to two groups with less than 2.6% each [32]. Nicotine has been shown to cause a delay in tendon-to-bone healing by causing chronic inflammation and decreased cell proliferation in rat studies [33]. In the current study setting, patients who developed delayed union were managed through protected weight bearing in a plaster cast to stimulate bone healing, as recommended [34 - 36]. Those who developed non-union underwent surgical intervention comprising open reduction and internal fixation (ORIF) with a nail, which has been found to improve the outcome [37].

There was a large proportion of complications among the patients who sustained open tibial fractures due to MVAs (27%), most of which were osteomyelitis and pin traction sepsis. MVAs have been classified as high-energy trauma, leading to extensive tissue and bone damage associated with complications, such as infection, delayed union, and non-union [25]. In this study, assault and gunshot injuries resulting in open tibial fractures accounted for 35% of the complications. South Africa has become one of the top-ranking violent countries in the world [38]. Some of the social dynamics that support violence in the country have been identified as widespread poverty, unemployment, income inequality, access to firearms, widespread illicit drug use, alcohol misuse, and weaknesses in law enforcement [14]. Osteomyelitis and pin tract sepsis were the complications with the highest proportions (28% and 19%, respectively) among all the patients presenting with open tibial fractures in the study setting. Prophylactic antibiotics and radical debridement have been found to improve the treatment outcome of open fractures [39]. These procedures were followed in the current study setting. However, the study did compare the outcome of patients who had received prophylactic antibiotic treatment *versus* those who did not; however, it was not the aim of the study. Nevertheless, the value of prophylaxis has been demonstrated in the literature [39].

About one in three of the patients evaluated for the number of days to the bone union had no risk factors. Almost two-thirds admitted to cigarette smoking, of whom more than a quarter had delayed union over 100 - 180 days, while 16% had delayed union, which warranted surgical intervention to achieve union. Recently, a study in Scotland estimated the incidence of tibial and fibula fractures at 5.5% per annum [40], and femoral and tibial shaft fractures have been shown to have the greatest odds of readmission [41]. The researchers in this current study could not find comparative figures in South Africa. The delayed and non-union have economic implications for the health system of a country. In the USA, the median cost of managing non-unions has been estimated at 25 556 USD per open tibial fracture, which is inclusive of healthcare utilization, prescriptions, and medication [42], while in the UK, the cost of hospital treatment of non-union has been estimated at £7 000 to £79 000 [43, 44]. There were no comparative studies that costed open tibial fractures in the South African context.

The limitations of the study were that it was conducted in one setting. Hence, its findings cannot be generalized to other settings. The authors acknowledge that there could have been hidden soft tissue injuries constituting an important reason for the development of bone infection and nonunion. The sampling method was time-bound with a relatively small sample size. However, most of the studies conducted on the subject displayed the characteristic of a small sample size [1, 9, 10].

CONCLUSION

This study has demonstrated that open tibial fractures affect mostly male patients who should be targeted for health educational awareness. The modes of injury with the highest proportions were MVA, PVA, gunshot, and assault. Since cigarette smoking is the risk factor found in the majority of the patients, which is also related to a high proportion of delayed union and non-union of the open tibial fractures, behavioural change towards quitting smoking should benefit patients with open tibial fractures. Antibiotics pre- and post-operatively should be adhered to by the managing clinicians to reduce sepsis, including osteomyelitis and pin tract infection, constituting the complications with the highest proportion of occurrence in this study.

LIST OF ABBREVIATIONS

DGMAH	=	Dr George Mukhari Academic Hospital
GA	=	Gustilo-Anderson
MVA	=	Motor Vehicle Accident
ORIF	=	Open Reduction and Fixation
PVA	=	Pedestrian Vehicle Accident

AUTHORS' CONTRIBUTIONS

CNS conceptualised the research idea as a part of his Master of Medicine (MMed) degree in orthopaedic surgery. SSG was the promoter, while LHM was the co-promoter who guided the student in conceptualizing the research idea, designing the protocol, collecting and analysing data, and compiling the manuscript. All authors approved the final manuscript for submission.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The project was approved by the Ethics Committee of Sefako Makgatho Health Sciences University Research and

Ethics Committee (SMUREC), Clearance Certificate Number: SMUREC/M/15/2016: PG).

HUMAN AND ANIMAL RIGHTS

No animals were used in the studies that are the basis of this research. All the humans were used in accordance with the ethical standards of the committee responsible for human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2013 (http://ethics.iit.edu/ecodes/node/3931).

CONSENT FOR PUBLICATION

Informed consent was obtained from all the patients.

AVAILABILITY OF DATA AND MATERIALS

The data supporting the findings of the article are available within the article.

STANDARDS OF REPORTING

STROBE guidelines were followed.

FUNDING

None.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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