



Effect of Gentamicin Addition to Normal Saline on Microbial Contamination and Early Wound Infection of Open Tibial Fractures

O. S. Oyagbesan*, O. O. Adegbehingbe, Oluwadare Esan

Department of Orthopaedic Surgery & Traumatology, Obafemi Awolowo University Teaching Hospitals Complex, Ile Ife, Nigeria

Email: *olusegunoyagbesan@gmail.com

How to cite this paper: Oyagbesan, O.S., Adegbehingbe, O.O. and Esan, O. (2024) Effect of Gentamicin Addition to Normal Saline on Microbial Contamination and Early Wound Infection of Open Tibial Fractures. *Open Access Library Journal*, 11: e11686. <https://doi.org/10.4236/oalib.1111686>

Received: May 12, 2024

Accepted: July 7, 2024

Published: July 10, 2024

Copyright © 2024 by author(s) and Open Access Library Inc.

This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

Abstract

Background: Infections continue to pose a significant challenge in the management of open tibia fractures, and the role of antibiotics in irrigation fluid remains unclear. **Objectives:** This study aimed to compare the pre- and post-irrigation bacteria colony counts of open tibia fractures in two irrigation groups: Normal Saline Fluid (NSF) and Normal Saline with Gentamicin (NSG). **Patients and Methods:** Fifty patients with Gustillo-Anderson I and II open tibia fractures were randomly assigned to either the NSF or NSG group. Pre-irrigation wound swabs were taken before randomization. Post-irrigation samples were collected, and patients were monitored weekly using the SOUTHAMPTON grading system for six weeks. Patients with clinical wound infection underwent wound culture. **Results:** Motor cycle injuries accounted for 56% of patients, with a modal age of 20 - 40 years and 75% male. Before irrigation debridement, the bacteria colony counts (BCC) were $20,056 \pm 9600$ cfu/ml and $22,456 \pm 21,150$ cfu/ml for NSF and NSG groups, respectively ($p = 0.608$). Post-irrigation, the BCC decreased to 8892 ± 4830 cfu/ml in the NSF group and 256 ± 341 cfu/ml in the NSG group ($p < 0.0001$). Seven (28%) NSF patients developed wound infection, primarily with staphylococcus, while none of the NSG patients were infected. **Conclusion:** Irrigation of open tibia fractures with normal saline impregnated with gentamicin fluid appears to reduce bacterial count load and early wound infection.

Subject Areas

Orthopedics

Keywords

Wound Irrigation, Bacteria Colony Counts, Open Fractures, Wound

1. Introduction

The management of open fractures poses persistent challenges to orthopedic surgeons, with the risk of wound infection remaining notably high across severity levels [1] [2]. Wound infections, ranging from superficial to chronic osteomyelitis, significantly elevate morbidity and treatment costs, often necessitating multiple surgeries, antibiotic regimens, and even amputations [3]. The risk of infection escalates due to the extensive soft tissue and osseous damage inherent in open fractures, further hindering wound healing and fracture union [3] [4].

To mitigate these complications, aggressive preventive measures are imperative, including meticulous wound evaluation, early debridement and irrigation, systemic antibiotics, local antibiotic delivery, and timely soft tissue coverage and fracture stabilization. Among these, wound irrigation and debridement are pivotal in reducing infection risk by mechanically removing debris and decreasing bacterial contamination [5]. While antiseptic solutions are generally avoided due to tissue toxicity, antibiotic fluids present a potential advantage by delivering antibiotics directly to the wound site, effectively targeting contaminating pathogens.

Previous animal and human studies have yielded conflicting results regarding the efficacy of antibiotic fluid irrigation in open fracture management [6] [7]. Some studies suggest benefits in reducing infection rates, while others report no significant difference compared to normal saline irrigation alone [6] [7]. Nevertheless, select human trials have demonstrated the superiority of antibiotic solutions over saline irrigation, particularly in high-risk wounds [8] [9]. Moreover, antibiotic irrigation in postoperative and intraoperative settings has shown promise in reducing surgical site infections [9].

Given the severe consequences of wound infections in open fractures and the promising findings from animal and human studies, further research is warranted to validate the efficacy of antibiotic fluid irrigation in reducing infection rates in open fracture wounds.

2. Materials and Methods

2.1. Study Design

This study was a prospective comparative cross-sectional study conducted over a 12-month period, following ethical clearance. The inclusion criteria were patients aged 18 - 65 years with Gustilo I - II open tibiofibular fractures presenting to the emergency unit. Exclusion criteria included patients with Gustilo III fractures, those presenting more than 6 hours post-injury, those with a previous drug reaction to gentamicin, and immunosuppressed individuals. A sample size of 50 was determined. Upon arrival at the emergency department, patients were

resuscitated using the ATLS protocol. Pre-debridement wound swabs were taken from the wound, and prophylactic intravenous ciprofloxacin was administered at presentation.

Patients were then randomized into two groups based on the choice of irrigation fluids used, using tallies labeled 1 - 50. Patients who picked odd-numbered tallies received normal saline only irrigation after debridement, while those with even-numbered tallies received normal saline with added gentamicin. Post-debridement swab samples were collected after debridement and bone stabilization. Wounds were sutured either by primary closure or delayed primary closure, depending on the discretion of the operating surgeon. Patients were observed weekly for clinical evidence of wound infection using the SOUTHAMPTON score, and microbiological evaluation was performed for those with clinical evidence of infection.

Information was entered into a structured proforma containing sections on biodata, mechanism of injury, Gustilo classification of fracture, nature of fracture, time of presentation, injury-debridement interval, pre-debridement vital signs, pre-debridement bacterial colony counts, post-debridement bacterial colony counts, weekly clinical evidence of wound infection, and microbiological evidence where clinical infection was suspected.

2.2. Statistical Analysis

Data relating to demographics, injury-related parameters, and treatment were compared between the two groups using cross-tabulation. The results of pre and post-debridement swab counts were compared between the two groups using t-tests and paired t-tests. In cases of infection during follow-up, the microbiological isolates were also analyzed in the two groups. The risk of infection between the two groups was compared using the Chi-square test.

Statistical analysis was conducted using the Statistical Package for the Social Sciences (SPSS) version 24, with results presented in **Tables 1-5** and **Figure 1**.

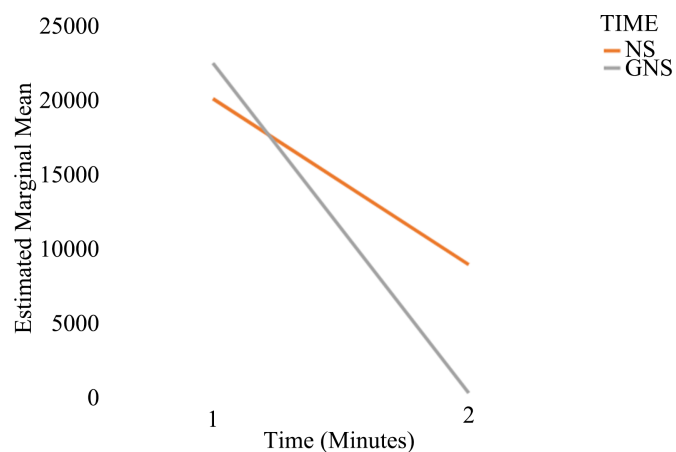


Figure 1. Objective 2: Effect of irrigation treatment on change in Swab Counts before and after irrigation. NS—normal saline group; GNS—Gentamicin in normal saline group. 1—pre-irrigation point in time; 2—post irrigation point in time.

Table 1. Sociodemographic data and injury related parameters.

Parameters		NS		GNS		p-Value
		n = 25	% (100)	n = 25	% (100)	
Sex	Male	20	80	19	76	
	Female	5	20	6	24	
Injury Mechanism	MCA	16	64	12	48	0.326
	MVA	6	24	11	44	
	Pedestrian	3	12	2	8	
Injury-Presentation Interval	<2 Hours	12	48	19	76	0.042
	2 - 4 Hours	11	44	3	12	
	>4.1 Hours	2	8	3	12	
Presentation-Debridement Duration	<1.5 Hours	17	68	15	60	0.210
	1.6 - 3 Hours	6	24	10	40	
	>3.1 Hours	2	8	0	0	
Gustillo-Anderson Grade	GA 1	4	16	5	20	0.713
	GA 2	21	84	20	80	
Fracture Sites	Proximal	0	0	2	8	0.066
	Middle	9	36	3	12	
	Distal	16	64	20	80	
Fracture Stabilization	Cast Immobilization	4	16	2	8	0.596
	External Fixation	5	20	4	16	
	Internal Fixation	16	64	19	76	

Note: MCA—Motorcycle Accident; MVA—Motor-Vehicular; Accident GA—Gustillo-Anderson.

Table 2. Distribution of isolates from pre-irrigation swabs.

<i>ISOLATES</i>	<i>n = 54 (%)</i>
<i>Staph aureus</i>	14 (25.9%)
<i>Bacillus species</i>	7 (13.0%)
<i>Corynebacteria species</i>	6 (11.1%)
<i>Proteus species</i>	6 (11.1%)
<i>Pseudomonas species</i>	5 (9.3%)
<i>Enterococcus species</i>	4 (7.4%)
<i>Micrococcus species</i>	3 (5.6%)
<i>Citrobacter species</i>	2 (3.7%)

Continued

<i>Escherichia coli</i>	2 (3.7%)
<i>Streptococcus species</i>	2 (3.7%)
<i>Klebsiella species</i>	2 (3.7%)
<i>Serrantia species</i>	1 (1.9%)
<i>Total</i>	54 (100%)

Table 3. Numbers of isolates in the pre and post irrigation Swabs.

No. of isolate(s) from swab	Pre-irrigation swabs n = 50 (100%)	Post-irrigation swabs n = 50 (100%)
0	0 (0%)	16 (32%)
1	11 (22%)	28 (56%)
2	30 (60%)	4 (8%)
3	9 (18%)	2 (4%)

Table 4. Objective 1: Pre- and post-debridement bacteria counts and irrigation groups.

Variable n = 25	Mean (SD)		Mean Difference (95% CI)	t-Statistics (df)	p-Value ^a
NS swab counts	Pre-irrigation	Post-irrigation	11,164 (6210, 16,118)	4.651 (24)	<0.001
	20,056 (9600) cfu/ml	8892 (4830) cfu/ml			
GNS swab counts	Pre-irrigation	Post-irrigation	22,200 (13,447, 30,593)	5.235 (24)	<0.001
	22,456 (21,150) cfu/mls	256 (341) cfu/mls			

Note: NS—normal saline group; GNS—gentamicin in normal saline group; cfu/mls—colony forming unit per milliliters; SD—standard deviation; CI—confidence interval. ^astatistical significance.

Table 5. Objective 2: Post-debridement swab counts and irrigation fluids.

Variable	Mean Post-debridement swab counts (SD)	Mean difference (95% CI)	t-Statistic (df)	p-Value ^a
NS	8892 (4830) cfu/mls	8636 (6689, 10,583)	8.918 (48)	<0.0001
GNS	256 (342) cfu/mls			

Note: NS—normal saline group; GNS—Gentamicin in normal saline group; SD—standard deviation; cfu/mls—colony forming units per milliliters. ^astatistically significant.

3. Results

During the study period, fifty patients who fulfilled the inclusion criteria were recruited and divided into two groups: Normal Saline irrigated (NS) and Gentamicin in Normal Saline irrigated (GNS), with twenty-five patients in each

group. The study revealed that patients aged 21 - 40 years had the highest incidence of open tibia fractures (54%), followed by those aged 41 - 60 years (18%). The mean age of the patients was 38 ± 15.7 years.

Table 1 above shows the sex distribution, injury and intervention parameters in the two groups compared, demonstrating that the two groups are quite comparable.

According to **Table 4**, analyzing the effects of the two interventions (NS and GNS) on the pre- and post-irrigation counts showed a significant reduction in the bacteria counts in the GNS group. Furthermore, the effect of the two interventions (taken at different points in time) using a 2-way repeated measures ANOVA demonstrated a significant reduction in swab bacterial counts ($F[1,48] = 46.87$, $p < 0.001$). Additionally, there was a significant interaction between the type of irrigation and the time factor (pre- and post-irrigation counts) ($F[1,48] = 5.129$, $p = 0.03$). A univariate analysis testing the single effect of irrigation fluids at each level of the other factor (time) showed a significant effect in the post-irrigation period ($F[1,48] = 79.5$, $p < 0.001$), based on linearly independent pairwise comparisons among the estimated marginal means. The profile plot of the estimated marginal means is illustrated in **Figure 1** above.

It is noted from the tables and **Figure 1** that irrigation (either with normal saline alone or with added gentamicin) produces a significant reduction in bacteria counts, with far greater effect in the antibiotic group (**Table 5**). In addition, there was a considerable reduction in the contamination rate in the GNS group (**Table 6**), and the risk of development of clinical wound infection was significantly higher in the normal saline alone group as shown in **Table 7**. The most consistent isolate in those patients who developed clinical wound infection on follow up is *Staphylococcus aureus* account for 10% as seen in **Table 8** and **Table 9**.

Table 6. Objective 2: Comparison of the effect of Normal saline and Gentamicin in normal saline in reducing wound contamination.

Irrigation fluids	No growth n (%)	Isolate grown n (%)	Total n (%)	X ² (df)	p-value	Remark
NS	3 (12)	22 (88)	25 (100)	6.349	0.012	significant
GNS	11 (44)	14 (56)	25 (100)	(1)		

Table 7. Objective 3: Comparison between Irrigation Fluids and rate of Wound Infection at follow-up.

Irrigation fluids	Clinical infection n (%)	No clinical infection n (%)	Total	X ²	p-Value	Remark
NS	7 (28%)	18 (72%)	25 (100%)	5.98	0.014	Significant
GNS	0 (0%)	25 (100%)	25 (100%)			

Note: NS—normal saline group; GNS—Gentamicin in normal saline group.

Table 8. Distribution of isolates cultured from patients with clinical wound infection during follow-up.

Microbial isolates	n (%)
Staphylococcus aureus	5 (10)
Pseudomonas species	2 (4)
Total	7 (14)

Table 9. Comparison of isolates from post irrigations swabs and swabs from cases with wound infection during follow-up.

Cases	Post-irrigation isolates	Follow-up isolates	Similar (%)	Dissimilar (%)
1	<i>Staph aureus</i>	<i>Staph aureus</i>		
2	Staph, Bacillus, Micrococcus	<i>Staph aureus</i>		
3	<i>Staph aureus</i>	<i>Pseudomonas spp.</i>		
4	<i>Staph aureus</i>	<i>Staph aureus</i>	5 (10%)	2 (4%)
5	Staph, pseudomonas and serantia	<i>Staph aureus</i>		
6	Bacillus, Pseudomonas	<i>Staph aureus</i>		
7	<i>Staph aureus</i>	<i>Staph aureus</i>		

4. Discussion

Open diaphyseal fractures are common in orthopedic practice, with open tibia fractures being the most frequent open long bone fractures. A previous study showed an incidence of 27.7% [10]. In terms of age prevalence, this study revealed that 54% of patients with open tibia fractures were between 20 and 40 years old, constituting the productive workforce of the population. This finding aligns closely with other studies. Ibeanusi *et al.* reported a prevalence rate of 70% in patients aged 20 to 39 years [11]. Generally, road traffic injuries are most common within this productive age group.

The study also showed a higher prevalence of open tibia fractures among males, with a male-to-female ratio of 3:1. This could be attributed to the higher activity levels of males, leading to increased road exposure compared to females. Ibeanusi *et al.* found a similar male-to-female ratio of 2.5:1 [11]. Additionally, Court-Brown *et al.* noted not only a higher prevalence in young adult males but also an increased prevalence among elderly females [10].

While several studies have identified road traffic injuries as the leading cause of open long bone fractures [10]-[12], this study categorized road traffic injuries into motor-vehicle accidents, motorcycle accidents, and pedestrian injuries based on the victims' mode of transportation. Motorcycle injuries accounted for the highest prevalence at 56%, followed by motor-vehicle injuries at 34%. This suggests that motorcycle injuries are more likely to result in open long bone fractures due to the unprotected nature of motorcycles and the lack of training

among many riders.

Although all patients presented within six hours of injury, the majority (60%) presented within the first two hours and underwent operative debridement and irrigation within 1.5 hours from presentation (64%). This may be due to the strategic location of our facility near a major highway. While early wound debridement is generally agreed to reduce the risk of infection, recent evidence challenges the “golden 6 hours rule” [13] [14]. Studies show no significant difference in infection incidence whether debridement is performed early or delayed, as long as appropriate antibiotic cover is established immediately [13] [14]. Challenges can arise when adhering strictly to this timing, such as operating under suboptimal conditions (e.g., lack of implants, surgeon fatigue).

Regarding antibiotic administration, 70% of patients received intravenous antibiotics within three hours of presentation, and all received intravenous cefuroxime for three days. The British Association of Plastic, Reconstructive and Aesthetic Surgeons (BAPRAS) guidelines recommend starting broad-spectrum antibiotics within three hours of injury, continuing until the first debridement [15]. The British Orthopaedic Association and the British Association of Plastic, Reconstructive, Aesthetic Surgeons (BOAST4 2017) recommend administering prophylactic intravenous broad-spectrum antibiotics within one hour of injury to reduce the risk of deep surgical site infection [16]. A meta-analysis on antibiotic prophylaxis for open fractures supports early systemic antibiotic administration [17].

The prevalence of Gustilo-Anderson grade II open fractures (82%) was higher than that of grade I open tibial injuries (18%). This may be because most patients in this study had moderate-severity injuries primarily from motorcycle (56%) and motor-vehicle (34%) accidents.

The distal tibia was the most common injury site, accounting for 72% of injuries. Bostman *et al.* indicated that torsional fractures often occur at the junction of the middle and distal third of the tibia, with additional axial compression causing more distal fractures [18]. The combination of torsional and axial forces likely contributes to road traffic injury-related tibia fractures.

Most patients (70%) had bone stabilization with open reduction and internal fixation using reamed locked intramedullary nails, following wound irrigation and debridement. Eighteen percent had external fixation, and 12% had cast immobilization. Early presentation and effective debridement made most injuries suitable for internal fixation, especially with minimal soft tissue injuries in Gustilo I and II fractures. Current evidence supports early bone stabilization with either external or internal fixation [19], which protects soft tissue, reduces potential dead space, and decreases infection rates.

Pathogens were isolated from all pre-irrigation wound swabs, indicating a 100% positive culture rate, while post-irrigation swabs had a 72% positive culture rate. This suggests that all open fractures should be considered potentially contaminated. Anderson (1976) reported a 70.3% positive bacterial culture rate in 1025 open long bone fracture wounds [20]. A study at Kenyatta National

Hospital found a 52.2% positive pre-debridement culture rate in 98 patients with open fractures presenting within 24 hours of injury [21]. Digvijay Agarwal *et al.* reported 51.42% positive pre-debridement and 34.28% positive post-debridement cultures [22]. These findings highlight the importance of irrigation and debridement in reducing microbial load.

This study found significant reductions in contamination levels following irrigation with gentamicin-laden normal saline compared to normal saline alone. Post-debridement and irrigation, 28% of swab samples (12% NS, 44% GNS) showed no growth, underscoring the efficacy of irrigation and debridement. The addition of local antibiotics in irrigation fluids further decontaminates open fractures. Halaz (1977) concluded that topical antibiotics significantly reduce infection rates in high-risk surgical wounds [8]. Few human trials, primarily on perioperative surgical wounds, have shown significant infection reduction with antibiotic irrigation fluids [9].

Of the pre-irrigation swabs, 78% yielded polymicrobial growths, and 22% yielded single bacterial isolates, indicating that open fracture wound contamination is mostly polymicrobial. Ojo *et al.* found polymicrobial growth in 53.7% of initial wound swabs in 60 patients with open fractures in southwestern Nigeria [23].

The major isolate from pre-irrigation wound swabs was *Staphylococcus aureus* (25.9%). Ikem *et al.*, in a similar study 14 years earlier, identified *Staphylococcus aureus* as the most commonly cultured organism (27%) [24]. This suggests that the pattern of wound contamination has not significantly changed over the years.

Irrigation and debridement significantly reduced microbial isolate counts, with mean bacterial counts decreasing from $21,256 \pm 16,300$ cfu/ml to 4574 ± 5124 cfu/ml, regardless of the irrigation fluid used. Both normal saline and gentamicin-normal saline were effective, but the antibiotic solution was associated with a greater reduction in bacterial load, as reflected by a further reduction in mean post-irrigation bacterial counts to 11,036 cfu/ml with gentamicin-normal saline. The beneficial effects of local antibiotic therapy in extensively contaminated open fractures are well-documented [8] [25]. Reducing the microbial load in post-debridement wounds with antibiotic irrigation fluids will ultimately reduce infection risk.

Patients in both groups (NS and GNS) were followed for six weeks. No patients in the GNS group developed clinical or microbiological evidence of infection, while seven (28%) in the NS group did. This suggests that gentamicin-normal saline is more effective in reducing wound contamination and early infection risk.

Among the seven patients who developed wound infections, *Staphylococcus aureus* was isolated in five cases (10%), and *Pseudomonas* species in four cases (4%). Earlier studies at the same center by Ikem *et al.* found *Staphylococcus aureus* and coagulase-negative *Staphylococci* as the most common isolates [24]. Similarly, Y Abu Hanifah *et al.* identified *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Klebsiella* species as the most common postoperative wound

isolates [26].

The study also showed that 71.4% of post-operative wound isolates were similar to those obtained immediately post-irrigation/debridement, suggesting that post-irrigation wound cultures can guide treatment in case of infection. A D'Souza *et al.* concluded that pre- and post-debridement cultures are valuable for detecting infections in open tibia fractures [27]. In 28.6% of cases, the bacterial isolates differed, implying a change in bacteriology over time.

In conclusion, comparing both irrigation fluids, gentamicin-normal saline was more effective in reducing post-debridement bacterial isolates ($p < 0.001$) and early wound infection risk ($p = 0.014$) compared to normal saline alone.

5. Conclusion

Irrigation and debridement significantly reduce contaminating bacterial load by about 4.5-fold. Adding gentamicin to normal saline irrigation fluid is more effective in reducing bacterial load than using normal saline alone. This translates to a better reduction in early wound infection rates in fractures irrigated with gentamicin-laden normal saline after six weeks of follow-up.

Conflicts of Interest

The authors declare no conflicts of interest.

References

- [1] Gustilo, R.B., Mendoza, R.M. and Williams, D.N. (1984) Problems in the Management of Type III (severe) Open Fractures. *The Journal of Trauma: Injury, Infection, and Critical Care*, **24**, 742-746. <https://doi.org/10.1097/00005373-198408000-00009>
- [2] Patzakis, M.J. and Wilkins, J. (1989) Factors Influencing Infection Rate in Open Fracture Wounds. *Clinical Orthopaedics and Related Research*, **243**, 36-40. <https://doi.org/10.1097/00003086-198906000-00006>
- [3] Doshi, P., Gopalan, H., Sprague, S., Pradhan, C., Kulkarni, S. and Bhandari, M. (2017) Incidence of Infection Following Internal Fixation of Open and Closed Tibia Fractures in India (INFINITI): A Multi-Centre Observational Cohort Study. *BMC Musculoskeletal Disorders*, **18**, Article No. 156. <https://doi.org/10.1186/s12891-017-1506-4>
- [4] Jorge-Mora, A., Amhaz-Escanlar, S., Ivan, C.G., Lopez-DelTeso, C., Gomez, R., *et al.* (2018) Management of Open Fracture. In: Ozgur, K. and Hakan, T., Eds., *Trauma Surgery*, IntechOpen, 11. <https://doi.org/10.5772/intechopen.74280>
- [5] Gabriel, A., Erik, D. and Schraga, M.D. (2017) Wound Irrigation Updated. <https://emedicine.medscape.com/article/1895071-overview#a1>
- [6] Rosenstein, B.D., Wilson, F.C. and Funderburk, C.H. (1989) The Use of Bacitracin Irrigation to Prevent Infection in Postoperative Skeletal Wounds: An Experimental Study. *The Journal of Bone & Joint Surgery*, **71**, 427-430. <https://doi.org/10.2106/00004623-198971030-00019>
- [7] Conroy, B.P., Anglen, J.O., Simpson, W.A., Christensen, G., Phaup, G., Yeager, R., *et al.* (1999) Comparison of Castile Soap, Benzalkonium Chloride, and Bacitracin as Irrigation Solutions for Complex Contaminated Orthopaedic Wounds. *Journal of Orthopaedic Trauma*, **13**, 332-337.

- <https://doi.org/10.1097/00005131-199906000-00002>
- [8] Halasz, N.A. (1977) Wound Infection and Topical Antibiotics. *Archives of Surgery*, **112**, 1240-1244. <https://doi.org/10.1001/archsurg.1977.01370100094021>
- [9] Lord, J.W., Rossi, G. and Daliana, M. (1977) Intraoperative Antibiotic Wound Lavage. *Annals of Surgery*, **185**, 634-641. <https://doi.org/10.1097/00000658-197706000-00004>
- [10] Court-Brown, C.M., Rimmer, S., Prakash, U. and McQueen, M.M. (1998) The Epidemiology of Open Long Bone Fractures. *Injury*, **29**, 529-534. [https://doi.org/10.1016/s0020-1383\(98\)00125-9](https://doi.org/10.1016/s0020-1383(98)00125-9)
- [11] Ibeanusi, S. and Ekere, A. (2007) Epidemiology of Open Tibial Fractures in a Teaching Hospital. *Port Harcourt Medical Journal*, **1**, 156-160. <https://doi.org/10.4314/phmedj.v1i3.38876>
- [12] Ikem, I., Oginni, L. and Bamgboye, E. (2001) Open Fractures of the Lower Limb in Nigeria. *International Orthopaedics*, **25**, 386-388. <https://doi.org/10.1007/s002640100277>
- [13] Werner, C.M.L., Pierpont, Y. and Pollak, A.N. (2008) The Urgency of Surgical Débridement in the Management of Open Fractures. *Journal of the American Academy of Orthopaedic Surgeons*, **16**, 369-375. <https://doi.org/10.5435/00124635-200807000-00002>
- [14] Schenker, M.L., Yannascoli, S., Baldwin, K.D., Ahn, J. and Mehta, S. (2012) Does Timing to Operative Debridement Affect Infectious Complications in Open Long-Bone Fractures? *Journal of Bone and Joint Surgery*, **94**, 1057-1064. <https://doi.org/10.2106/jbjs.k.00582>
- [15] Nanchahal, J., Nayagam, S., Khan, U., Moran, C., Barrett, S., Sanderson, F. and Pallister, I. (2009) Standard for the management of Open Fractures of the Lower Limb. Reviewed by British Association of Plastic, Reconstructive and Aesthetic Surgeons. Royal Society of Medicine Press Ltd.
- [16] British Orthopaedic Association and the British Association of Plastic (2018) Reconstructive, Aesthetic Surgeons. Standard for Trauma—2009. BOAST 4: The Management of Severe Open Lower Limb Fractures.
- [17] Chang, Y., Bhandari, M., Zhu, K.L., Mirza, R.D., Ren, M., Kennedy, S.A., et al (2019) Antibiotic Prophylaxis in the Management of Open Fractures. *JBJS Reviews*, **7**, e1. <https://doi.org/10.2106/jbjs.rvw.17.00197>
- [18] Böstman, O. (1983) Morphological Observations of Torsional Fractures of the Adult Tibial Shaft. *Acta Orthopaedica Scandinavica*, **54**, 627-633. <https://doi.org/10.3109/17453678308992901>
- [19] Swiontkowski, M. and Cross III, W. (2008) Treatment Principles in the Management of Open Fractures. *Indian Journal of Orthopaedics*, **42**, 377-386. <https://doi.org/10.4103/0019-5413.43373>
- [20] Gustilo, R. and Anderson, J. (1976) Prevention of Infection in the Treatment of One Thousand and Twenty-Five Open Fractures of Long Bones. *The Journal of Bone & Joint Surgery*, **58**, 453-458. <https://doi.org/10.2106/00004623-197658040-00004>
- [21] Sitati, F.C., Mosi, P.O. and Mwangi, J.C. (2018) Early Bacterial Cultures from Open Fractures—Differences before and after Debridement. *Annals of African Surgery*, **14**, 66-70. <https://doi.org/10.4314/aas.v14i2.3>
- [22] Agarwal, D., Maheshwari, R., Agrawal, A., Chauhan, V. and Juyal, A. (2015) To Study the Pattern of Bacterial Isolates in Open Fractures. *Journal of Orthopedics, Traumatology and Rehabilitation*, **8**, 1-5. <https://doi.org/10.4103/0975-7341.183953>

- [23] Ojo, O.D., Oluwadiya, K.S., Ikem, I.C., Oginni, L.M., Ako-Nai, A.K. and Daniel, F.V. (2010) Superficial Swab Cultures in Open Fracture Management: Insights from a Resource-Poor Setting. *Journal of Wound Care*, **19**, 432-438. <https://doi.org/10.12968/jowc.2010.19.10.79090>
- [24] Ikem, I.C., Oginni, L.M., Bamgboye, E.A., Ako-Nai, A.K. and Onipede, A.O. (2004) The Bacteriology of Open Fractures in Ile-Ife, Nigeria. *Nigerian Journal of Medicine*, **13**, 359-365.
- [25] Glotzer, D.J. (1970) Topical Antibiotic Prophylaxis in Contaminated Wounds. *Archives of Surgery*, **100**, 589-593. <https://doi.org/10.1001/archsurg.1970.01340230055012>
- [26] Abu Hanifah, Y. (1990) Post-Operative Surgical Wound Infection. *Medical Journal of Malaysia*, **45**, 293-297.
- [27] D'Souza, A., Rajagopalan, N. and Amaravati, R. (2008) The Use of Qualitative Cultures for Detecting Infection in Open Tibial Fractures. *Journal of Orthopaedic Surgery*, **16**, 175-178. <https://doi.org/10.1177/230949900801600209>