Outcome of External Fixator Management of Gustilo Anderson Type III Tibial Fractures in Lagos University Teaching Hospital

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ABSTRACT

Type III open tibial fracture is the commonest type of open tibia fracture. The aim of this study was to determine the outcome of Gustilo-Anderson type III open tibial fracture managed with external fixator. Patients that presented with Gustilo-Anderson type III open tibial fractures were recruited. Patients with bone pathology, prior debridement and concomitant spinal cord injury were excluded. Ethical approval and informed consent were obtained. A structured proforma was used to collect the participant's socio-demographic data, time of injury, fracture location, interval and number of debridement, need for skin graft or flap, duration of hospital stay, outcome of treatment, complications and events at follow-up. Wound biopsy was taken and processed for microscopy, culture, and sensitivity. Delayed union was diagnosed when the fracture united between 4-6 months. Non-union was defined as a varus or valgus angulation of >5 degrees or anterior or posterior angulation of >10 degrees. Patients were followed up for 6 months. Chi square was used to determine association between categorical variables. SPSS 20 was used for analysis. Significance was p value <0.05. Of 35 patients, males were 22 (62.9%) while females were 13 (37.1%) and mean age was 38 years. Average interval between injury and presentation was 14.5 hours. Fourteen (40%) patients had type IIIA, 18 (51.4%) patients had type IIIB while 3 (8.6%) patients had type IIIC. Mean time to fixation was 59.2 hours. Wound infection, malunion, delayed union, pin loosening and compartment syndrome were found in 42.9%, 21.3%, 21.3%, 11.5% and 1.6% respectively. Infection rate was significantly positively correlated with grade of fracture ($p=0.04$) and time to debridement ($p=0.018$). A significant association between the mechanism of injury and associated injury ($p=0.027$) but not mechanism of injury and grade of type III fracture ($p=0.292$). Significant difference between the duration of hospital stays and categories of type III fractures ($p=0.026$) but not associated injury ($p=0.403$). No significant difference in location of fracture and time of union ($p=0.723$). Type III fractures managed with external fixator is associated with some complications among which infection is the commonest and delay in treatment is associated with higher risk. Post-debridement microscopy and culture is a better predictor of wound infection.

Keywords: External Fixator, Gustilo Anderson, Outcome, Type III Tibial Fracture.

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I. INTRODUCTION

Traumatic injuries are major causes of death and disability globally [1]. Trauma accounts for most fractures of the lower limbs [2]. High-speed lifestyles, with motor vehicles and motorcycles, contribute to the increasing incidence of lower limb fractures in contemporary society [3]-[5]. Fractures can be closed or open. Open fractures are fractures that communicate with the external environment through a skin wound [6]. Despite the discovery and use of antibiotics following injuries, infection continues to be an important

challenge in open fractures leading to longer hospital stays, increased cost of treatment, morbidity and mortality [7]. Deep fracture-site infections can lead to chronic osteomyelitis, non-union, loss of function, or even limb loss.

Open tibial fractures are typically classified using the system proposed by Gustilo and Anderson [8] and later modified by Gustilo and colleagues [9]. Gustilo et al [8] classified open fractures into three categories: Type I, II and III. Gustilo Anderson Type III open tibial fracture is the commonest type of open tibia fracture [10], [11]. Type III tibia fracture is further subdivided into three subcategories;

IIIA: adequate soft tissue coverage of a fractured bone despite extensive soft tissue laceration or flaps, or high energy trauma irrespective of the size of the wound; IIIB: extensive soft tissue injury loss with periosteal stripping and bone exposure usually associated with massive contamination; and IIIC: open fractures associated with arterial injury requiring repair. Despite reported poor inter-observer agreement in its use, this system is prognostic with respect to complications associated with open fractures [9], [12].

The major aim of management of open fractures is to halt bacterial proliferation in the wound, remove dead and nonviable tissues by extensive wound debridement, ensure adequate coverage of exposed bone and achieve stable skeletal fixation to allow for fracture healing [13]. Following Gustilo Anderson type III tibial fractures, most common technique of skeletal stabilization is the use of external fixators [14]. External fixation is popular because of the relative ease of application, provision of immediate stabilization, provision of space for management of associated soft tissue injuries and the limited effect on the blood supply of the tibia [15]-[17]. Soft tissue bone cover may be accomplished by delayed primary closure, split thickness skin graft, local muscle flap rotation, or free tissue transfer with microvascular anastomosis.

Gustilo and Anderson Type III open tibial fracture is fraught with infection and other complications. Most of the bacteria isolated in the pre-debridement are usually contaminants. There is need to assess the value of post-debridement bacteria isolate with the development of wound infection as a guide to the use of empirical antibiotics. Moreover, it is important to assess the management outcome. The aim of this study was to determine the outcome of Gustilo-Anderson type III open tibial fracture managed with external fixator.

II. PATIENTS AND METHODS

This was a 12-month prospective hospital-based study conducted in Lagos University Teaching Hospital (LUTH) Idi- araba, Lagos. All patients that presented with Gustilo-Anderson type III open tibial fractures with or without involvement of the fibula within this period were recruited into the study. Patients with underlying bone pathology, who had debridement before arrival to LUTH, who had concomitant spinal cord injury and those who withheld consent were excluded from participating in the study. Ethical approval was obtained from the Hospital Ethics and Research Committee before commencement of the study, written informed consent was obtained before enrolling each patient into the study. A structured proforma was used to collect the participant's socio-demographic data, time of injury, fracture location, interval and number of debridement, need for skin graft or flap, duration of hospital stay, outcome of treatment, complications and events at follow-up.

All open tibial fractures were treated as surgical emergencies. Wound biopsy was taken before antibiotic treatment, immediately after debridement and whenever there is established suppuration. All the wound specimens were processed for microscopy, culture and sensitivity. Plain x-ray films (anteroposterior and lateral views) were taken of the bones of the affected limb after temporary splintage. Anti-

tetanus prophylaxis was given at presentation. Intravenous ceftriaxone (in combination with metronidazole if there is gross soilage, farmyard injury or gunshot injury) was given for the first 72 hours. Wound debridement was repeated at 48 hours interval until wound was clean and all necrotic tissue removed. Wounds that were categorized after debridement as Gustilo-Anderson type III had external fixator applied. Soft tissue management included delayed primary closure after three to five days, secondary closure and split thickness skin grafting and flap. The flap was a local flap using the soleus for middle third soft tissue defect and fascio-cutaneous for distal third defects. The skin graft and flaps were done fourteen days post injury.

The outcome of treatment was determined with respect to the time of fracture union and presence of complications. Fracture union was assessed clinically (by minimal tenderness at fracture site and ability to 'squat and smile') and by radiology at 6 weeks, 3 months and 6 months. A fracture was considered united if there was no pain, tenderness or abnormal movement at the fracture site and bridging callus was visible on radiograph- crossing 3 or 4 cortices. Delayed union was diagnosed when the fracture united between 4-6 months. Non-union was defined as a varus or valgus angulation of >5 degrees or anterior or posterior angulation of >10 degrees. Infection was determined by clinical findings of local erythema, swelling, tenderness or a purulent discharge and a positive bacterial culture. The functional evaluation was based on pain, range of motion, and ability to return to normal work. Patients were followed up after discharge in the clinic monthly for 6 months.

The results of this study were analyzed by descriptive statistical methods such as range, means and standard deviation. Chi square was used to determine association between categorical variables. SPSS 20 was used for analysis. Significance was considered as p value < 0.05.

III. RESULTS

Out of 78 patients that met the inclusion criteria, 26 left against medical advice and 17 were excluded due to inability to pay for surgery which resulted in the conservative management using plaster of Paris back-slab. Of the 35 patients that were analyzed, males were 22 (62.9%) while females were 13 (37.1%) with a male to female ratio of 1.7:1. The age range of the patients was 3 -87 years to 87 years with a mean age of 38 years and a median age of 35 years. Of the 35 patients in the study, 14 (40%) were traders, 8 were students, 8 were civil servants and 5 patients were either retired or unemployed.

The average time interval between injury and presentation to the hospital was 14.5 hours (2-72 hours). Road traffic crashes accounted for 48.6% of open tibial fractures as in Table I (showing mechanism of injury). There were associated injuries in 34.3% of patients studied and the most common associated injury was traumatic brain injury (Table II). Concomitant fibula fracture was found in 32 (91.4 %) patients while the remaining 3 (8.6%) had isolated tibia fracture. The right tibia was involved in 21 of the patients while the left tibia was involved in 14 giving a right to left ratio of 1.5:1. Fourteen (40%) patients had type IIIA, 18 (51.4%) patients had type IIIB while 3 (8.6%) patients had

type IIIC. The age group from 21-40 years represented the group with the highest frequency and the three categories of type III open tibia fracture were higher in this age group as shown in Fig. 1.

TABLE I: DISTRIBUTION OF MECHANISM OF INJURY

Mechanism of Injury	Frequency	%
Fall	4	11.4
Gunshot	1	2.9
Motorcycle	4	11.4
Motor vehicular	11	31.5
Tricycle	2	5.7
Pedestrian-traffic injury	13	37.1
Total	35	100.0

TABLE II: INJURIES ASSOCIATED WITH GA III OPEN TIBIAL FRACTURES.

Associated Injury	Frequency	Percent (%)
Blunt Abdominal Injury (ABD)	2	5.7
Other Long Bone Fractures	1	2.9
Traumatic Brain Injury (TBI)	7	20
TBI+ Blunt Chest Injury	1	2.9
TBI + ABD	1	2.9
No Associated Injury	23	65.7
TOTAL	35	100

Fig. 1. Bar chart showing age groups and fracture grade among the patients.

Analysis of the pattern of fracture shows that the distal 3rd of the tibia is most involved as shown in Table III. The mean time from fracture to surgical debridement and external fixation was 59.2 hours (range 6-140 hours). Fifteen (42.9%) patients were operated within forty-eight hours while 20 (57.1%) were operated after 48 hours. Thirty patients (85.7%) had single debridement while 5 patients (14.3%) had multiple wound debridement. Multiple debridement was done in 7.1% of IIA, 16.7% of IIB and 33.3% of IIC.

The commonest complication was wound infection noted in 15 patients (42.9%). Malunion and delayed union each was found in 13 (21.3%) patients. Pin loosening was found in 7 patients (11.5%). Pin-site infections with a discharge and cellulitis were seen in 4 patients (6.6%), and were controlled with a short course of antibiotics. Compartment syndrome accounted for 1.6% of complications. The infection rates for each grade of type III tibial fracture were as shown in Table IV.

TABLE III: DISTRIBUTION OF FRACTURE PATTERNS

Fracture pattern	Proximal n (%)	Middle n (%)	Distal n (%)	Frequency	Percent %
Communitied	0 (0)	0 (0)	9 (25.7)	9	25.7
Oblique	2 (5.7)	5 (14.3)	4 (11.4)	11	31.4
Transverse	2 (5.7)	4 (11.4)	5 (14.3)	11	31.4
Segmental	0 (0)	1 (2.9)	0 (0)	1	2.9
Spiral	0 (0)	2 (5.7)	1 (2.9)	3	8.6
Total	4 (11.4)	12 (34.3)	19 (54.3)	35	100.0

TABLE IV: INFECTION RATES OF THE GRADES OF TYPE III TIBIAL FRACTURE

Grade of III Tibia Fracture	Frequency of Wound Infection	Total	Percent
IIIA	4	14	28.6
IIIB	8	18	44.4
IIIC	3	3	100
TOTAL	15	35	42.9

The infection rate was significantly higher in patients with higher grade of type III open tibial fracture than those with lower grade ($p=0.04$) and there was also statistically significant difference ($p=0.018$) between time of debridement and development of wound infection Table V. There was a statistically significant association between the mechanism of injury and associated injury ($p=0.027$). There was no statistically significant correlation between mechanism of injury and grade of type III fracture ($p=0.292$).

TABLE V: TIME INTERVAL BEFORE DEBRIDEMENT AND WOUND INFECTION

Time to Debridement	Infection	No Infection	Total
< 48 hours	3(20%)	12 (80%)	15
>48 hours	12(60%)	8 (40%)	20
Total	15	20	

Result of management of associated soft tissue injuries is as shown in Table VI. All the patients that had primary wound closure healed without complication. One of the patients with type IIIA open tibial fracture that had delayed primary closure had superficial wound dehiscence.

The average length of stay was 4.3 weeks with a range of 2 weeks to 10 weeks (Table VII). There was a significant difference between the duration of hospital stay among different categories of type III fractures ($p=0.026$). There was no significant difference between hospital stay in patients with associated injury and those without ($p=0.403$).

TABLE VI: SOFT TISSUE MANAGEMENT OF OPEN WOUND IN TYPE III OPEN TIBIAL FRACTURE

Wound closure methods	IIIA n (%)	IIIB n (%)	IIIC n (%)
PC	5 (35.7)	0 (0)	0 (0)
DPC	6 (42.9)	0 (0)	0 (0)
SC	3 (21.4)	8 (44.4)	0 (0)
SG	0 (0)	5 (27.8)	0 (0)
Flap	0 (0)	5 (27.8)	3 (100)
Total	14 (100)	18 (100)	3 (100)

PC = Primary Closure; DPC = Delayed Primary Closure; SC = Secondary Closure; SG = Skin graft.

TABLE VII: DURATION OF HOSPITAL STAY

Grade	Mean±SD (weeks)	Range (weeks)
IIIA	3.8±1.2	2-6
IIIB	4.3±1.4	3-8
IIIC	8.3±2.1	6-10

The average union time was 15.2 ± 4.8 weeks with a range of 10-26 weeks. There was no significant difference in location of fracture (proximal, middle, or distal third tibial fracture) and time of union ($p=0.723$). There was also no statistically significant relationship between the presence of wound infection with occurrence of nonunion ($p=0.631$).

IV. DISCUSSION

In an average population, there occurs approximately two tibial shaft fractures per 1,000 individuals and there are about 26 tibial diaphyseal fractures per 100,000 of the population per year [18], [19]. The peak age incidence of open tibial fracture is in the 20-40 years age group [10], [20], [21].

A male preponderance with a male to female ratio of 1.7:1 was found in this study similar with findings in other studies [11], [22], [23]. This is because males are more involved in commercial transportation as drivers and cyclist. Furthermore, males generally move about more and indulge in high energy activities. In this study, pedestrian and motor vehicular accidents accounted for most of the injuries. Open tibia fracture was more in the right than left tibia according to studies by Alabi [24] and Oguachuba [25]. This is similar with the finding in this study.

The peak age group of open tibial fracture in this study is 21-40 years with a mean of 38 years and the commonest grade was IIIB (51.4%). The distal third of the tibia was the most affected (54.3%). These findings were similar with findings with other studies [11], [23]-[25]. There was no statistical significance between the cause of injury and severity of open tibia fracture. This was similar to a study by Ifesanya et al [11]. The commonest fracture patterns found were oblique and transverse fractures (31.4%). This was different from another study in western Nigeria that showed comminuted fracture pattern to be more [23]. This difference in fracture pattern may be due to differences in sociodemographic patterns and the fact that use of commercial motorcycles as a means of transportation have been banned on Lagos highways.

The average interval from injury to presentation found in this study is 14.5 hours. The cause of delay in presentation ranged from paucity of bed space, traffic jam, and initial treatment by traditional bone setters and private hospitals. Most of the patients were referred from private and general hospitals. This delays in presentation have been documented in other studies in Nigeria [11], [20]. There is, therefore, need for investment in development of the health system of Nigeria and other third world countries. There is also need for development of means for fast and efficient transportation of victims of road traffic accidents to centers where they can get appropriate management to obviate the constraints posed by poor road networks and traffic jams.

The mean interval to debridement was 59.2 hours (6-140 hours). This was higher than found in most literature [23], [26]. The reasons for delay included operating room availability, financial burden, patient instability, and general or neurosurgical priority intervention. The most significant reason for delay in surgical intervention was financial constraint (89%). Studies have shown that majority of the victims of fractures are in the low-income class [20], [24]. Payment is usually required before use of theatre space and

for provision of external fixator set and other sundries for surgery. In Canada, Hull et al [26] found a significant increase in the rate of deep infection for each hour of delay among the grades II and III fractures but did not specify any distinct cut-off point. In this study the rate of increase in infection became statistically significant after 48 hours of delay ($p=0.02$). Although Dellinger and colleagues [27] reported no statistical significance in timing to operative treatment and risk of infection, electing to delay the treatment of open fractures is not recommended [28].

This study showed an infection rate of 42.9%. The infection rate observed in the literature ranged from 2% to 47% [8], [9], [29]-[31]. The reasons for high rate of infection include relatively poor osseous blood supply, limited soft tissue coverage and late presentation. In this study, *Staphylococcus aureus* (27.7%), *Proteus spp* (27.7%), *Klebsiella spp* (24.3%) and *Staphylococcus epidermidis* (20%) were the common organisms isolated. The post-debridement microscopy and culture predicted wound infection than pre-debridement microscopy and culture and this was upheld by a study by Merritt [32].

A total of 42.9 % of IIIA had delayed primary closure because of tissue edema and potential contamination and 35.7% of IIIA had straight forward primary closure. The remaining 21.4% had secondary closure mainly because of wound breakdown and infection. All type IIIB and IIIC soft tissue management was treated by open wound principle of dressing with repeated serial debridement for weeks, followed by delayed wound coverage. We noticed that wound coverage after very long periods of dressing was more difficult because tissue planes had become obscured and difficult to access.

We found a union time of 15.2 ± 4.8 weeks with a range of 10-26 weeks. Ifesanya [10] reported mean union time of 26.2 ± 12.7 weeks with a range of 17-56 weeks. Their value was higher than the value in this study because they had a longer follow up time. This study had a follow up of 6 months and some fractures might not have united within this period. There was no statistically significant difference between union times in the anatomic location i.e., comparing proximal, middle and distal third tibial fracture. ($p=0.723$). Hence location of fracture is not an important determinant of union.

We found a significant correlation between severity of open tibia fracture and septic complications ($p=0.04$). Ifesanya et al [10] found a similar association. Court-Brown et al [33] reported pin site infection of 25% in IIIA and 50% of the IIIB fractures. This study showed pin site infection of 6.6% and pin loosening of 11.5%, thus pin-related complication of 18.1%. Chan et al [34] documented a 41% incidence of malunion. Our study showed a malunion and delayed union rate each of 23.1%. The lowers incidence of malunion and delayed union in our study can be attributed to lower severity of tibia fracture. It has been shown that higher grades of type III fractures carry a significantly worse prognosis in the time to union, number of amputations and the marked increase in the incidence of osteomyelitis [33].

Caudle and Stern [17] found the average hospitalization time for *isolated* IIIB fractures in their series to be 31.5 days. This time was more than that of the patients with IIIA fractures but was similar with that for the multiply injured

patients with IIIB fractures. This suggests that it was the IIIB fracture that was the main determining factor for duration of hospital stay. This study's finding that the grade of type III open tibia fracture was the significant factor in determining hospital stay and not necessarily the associated injuries was in consonance to their finding.

V. CONCLUSION

Road traffic accidents are the main cause of type III open tibial fractures in our environment. Type III fractures managed with external fixator is associated with some complications among which infection is the commonest and delay in treatment is associated with higher risk of infection. Post-debridement microscopy and culture is a better predictor of wound infection than pre-debridement microscopy and culture. Adequate and early debridement and stabilization is important for good outcome. Early referral and implementation of universal health insurance scheme may help to enhance prompt management and better outcome by reducing delay in presentation and delay in management occasioned by financial constraint.

REFERENCES

- [1] J. Poorolajal, "Neglected major causes of death much deadlier than COVID-19," *J Res Health Sci*, vol.20, no. 2, pp. e00478, May. 2020.
- [2] R. M. Baerov, A. M. Morega, and M. Morega, "Analysis of magnetotherapy effects for post-traumatic recovery of limb fractures," *Rev. Roum. Sci. Techn.-Électrotechn. et Énerg*, vol. 65, pp. 1-2, Jan. 2020.
- [3] A. U. Ekere, "Simple patterns and definitive treatment of open tibial fracture: a private practice experience in PortHarcourt, Nigeria," *Niger J Gen Pract*, vol. 7, pp. 21-24, 2003.
- [4] Department of Transport. Transport statistics report, *International comparisons of transport statistics 1970-1994*, London: Department of Transport;1997, pp. 1-5.
- [5] A. U. Ekere, and U. S. Etuk, "Pattern of road vehicular trauma in Port Harcourt. A prospective analysis of 180 victims," *Trop J Med Res*, vol. 6, pp. 14-19, 2002.
- [6] C. J. Hauser, C. A. JR Adams, and S. R. Eachempati, "Council of the Surgical Infection Society. Surgical infection society guideline: prophylactic antibiotic use in open fractures: an evidence-based guideline," *Surg. Infect*, vol. 7, no. 4, pp. 379-405, Aug. 2006.
- [7] D. R. Tribble, N. G. Conger, S. Fraser, T. D. Gleeson, G. Wilkins, and M. L. Landrum, "Infection-associated clinical outcomes in hospitalized medical evacuees after traumatic injury: trauma infectious disease outcome study (TIDOS)," *J Trauma*, vol. 71, no. 10, pp. 533-542, Jul. 2011.
- [8] R. B. Gustilo, and J. T. Anderson, "Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and analyses," *J Bone Joint Surg Am*, vol. 58, no. 4, pp. 453-458, Jun. 1976.
- [9] R. B. Gustilo, R. M. Mendoza, and D. N. Williams, "Problems in the management of type III (severe) open fractures: a new classification of type III open fractures," *J Trauma*, vol. 24, no. 8, pp. 742-746, Aug. 1984.
- [10] A. O. Ifesanya, A. B. Omololu, S. O. Ogunlade, and T. O. Alonge, "The burden of open fractures of the tibia in a developing economy," *Nig J Plast Surg*, vol. 6, no.1, pp. 32-39, Mar. 2010.
- [11] A. O. Ifesanya, T. O. Alonge, S. O. Ogunlade, A. B. Omololu, and T. E. Nottidge, "Changing trends in the pattern of tibial fractures in Nigeria: a review of 70 cases," *J. Orthop*, vol. 5, no. 2, pp. e4, Feb. 2008.
- [12] A. Aljawadi, A. Islam, N. Jahangir, N. Niazi, M. Elmajee, A. Reid, J. Wong, and A. Pillai, "One-stage combined "fix and flap" approach for complex open Gustilo-Anderson IIIB lower limbs fractures: a prospective review of 102 cases," *Arch Orthop Trauma Surg*, vol. 3, pp.1-10, Jan. 2021.
- [13] D. C. Templeman, B. Gulli, D. T. Tsukayama, and R. B. Gustilo, "Update on the management of open fractures of the tibial shaft," *Clin Orthop Relat Res*, vol. 1, no. 350, pp. 18-25, May 1998.
- [14] T. O. Alonge, S. O. Ogunlade, S. A. Salawu, and A. T. Adebisi, "Management of open tibia fracture- Anderson and Hutchins technique re-visited," *Afr J Med Med Sci*, vol. 32, no. 2, pp. 131-134, Jun. 2003.
- [15] P. M. Rommens, D. E. Van Raemdonck, and P. L. Broos, "Reosteothesis of the tibial shaft. Part I. Changing of procedure after external fixation," *Acta Chir Belg*, vol. 89, no. 5, pp. 281-286, Sep. 1989.
- [16] R. M. Puno, J. T. Teynor, J. Nagano, and R. B. Gustilo, "Critical analysis of results of treatment of 201 tibial shaft fractures" *Clin Orthop*, vol. 212, pp. 113-121, Nov. 1986.
- [17] R. J. Caudle, and P. J. Stern, "Severe open fractures of the tibia," *J Bone Joint Surg Am*, vol. 69, no. 6, pp. 801-807, Jul. 1987.
- [18] A. N. Alho, J. G. Benterud, H. E. Høgevoid, A. Ekeland, and K. Stromsoe, "Comparison of functional bracing and locked intramedullary nailing in the treatment of displaced tibial shaft fractures," *Clin Orthop*, vol. 1, no. 277, pp. 243-250, Apr. 1992.
- [19] C. M. Court-Brown, and J. McBirnie, "The epidemiology of tibial fractures," *J Bone Joint Surg Br*, vol. 77, no. 3, pp. 417-421, May 1995.
- [20] S. E. B. Ibeanusi, and A. U. Ekere, "Epidemiology of open tibial fracture in a Teaching Hospital," *Port Harcourt Medical Journal*, vol. 1, no. 3, pp. 156-160, Aug. 2007.
- [21] P. Umebese, M. Moin, and O. West, "Early management of open tibial fractures in Benin City- Result of a structured treatment protocol," *Journal of Medicine and Biomedical Research*, vol.5, no. 2, pp. 33-39, Mar. 2006.
- [22] B. O. Onabowale, J. E. Onuminya, I. A. J. Essien, and N. D. Ukegbu, "The management of open tibial shaft fractures. The National Orthopaedic Hospital Experience," *Nig J Surg*, vol. 2, pp. 37-42, 1995.
- [23] I. C. Ikem, L. M. Oginni, and J. D. Ogunlusi, "Determinants of management outcome in open tibial fractures in Ile-ife," *Nigerian Journal of Surgical Research*, vol. 8, no. 1-2, pp. 81-85, 2006.
- [24] Z. O. Alabi, "The pattern of tibial fractures in Ilesha Nigeria," *Niger Med J*, vol. 11, pp. 22-29, 1981.
- [25] H. N. Oguachuba, "The pattern of tibial and fibula fractures: NOHE experience," *Niger J Surg*, vol.2, pp. 24-27, 1995.
- [26] P. D. Hull, S. C. Johnson, D. J. G. Stephen, H. J. Kreder, and R. J. Jenkinson, "Delayed debridement of severe open fractures is associated with a higher rate of deep infection," *Bone Joint J*, vol. 96, no. 3, pp. 379-384, Mar. 2014.
- [27] E. P. Dellinger, S. D. Miller, M. J. Wertz, M. Grypma, B. Droppert, and P. A. Anderson, "Risk of infection after open fractures of the arm or leg," *Arch Surg*, vol. 123, no. 11, pp. 1320-1327, Nov. 1988.
- [28] M. L. Schenker, S. Yannascoli, K. D. Baldwin, J. Ahn, and S. Mehta, "Does timing to operative debridement affect infectious complications in open long-bone fractures? A systematic review," *J Bone Joint Surg Am*, vol. 94, no. 12, pp. 1057-1064, Jun. 2012.
- [29] R. B. Gustilo, R. L. Merkow, and N. D. Templeman, "Current concepts review: The management of open fractures," *J Bone Joint Surg Am*, vol. 72, no. 2, pp. 299-304, Feb. 1990.
- [30] M. W. Chapman MW, "Open Fractures," in *Operative Orthopaedics*. 2nd ed, M. W. Chapman MW, Ed. Philadelphia: JB Lippincott Company 1993, pp. 365-372.
- [31] P. A. Blachut, R. N. Meek, and P. J. O'Brien, "External fixation and delayed intramedullary nailing of open fractures of the tibial shaft," *J Bone Joint Surg Am*, vol. 72, no. 5, pp. 729-735, Jun. 1990.
- [32] K. Merritt, "Factors increasing the risk of infection in patients with open fractures," *J Trauma*, vol. 28, no. 6, pp. 823-827, Jun. 1988.
- [33] C. M. Court-Brown, M. M. McQueen, A. A. Quabba, and J. Christie, "Locked intramedullary nailing of open tibial fractures," *J Bone Joint Surg Br*, vol. 73, no. 6, pp. 959-964, Nov. 1991.
- [34] K. M. Chan, Y. K. Leung, J. C. Y. Cheng, and P. C. Leung, "The management of type III open tibial fractures," *Injury*, vol.16, no. 3, pp. 157-165, Nov. 1984.