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GUNSHOT FRACTURES OF TIBIA AND FEMUR - EXCELLENT RESULTS WITH REAMED BONE MARROW GRAFT AND INTERLOCKING NAILING
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J. D. OGUNLUSI, A. OLASINDE, I. C. IKEM and T. DAVIDS

ABSTRACT

***Objective*: To document the outcome of treatment of femur and tibia diaphyseal fractures due to gunshot injury grafted with reamed bone marrow and immobilised with Surgical Implant Generation Network (SIGN) interlocking nail.**
***Design*: A prospective study.**
***Setting*: Three referral centres in two developing countries**
***Subjects*: Thirty-three patients with 36 fractures due to gunshot injury were studied.**
***Interventions*: Stabilised patients were commenced on prophylactic parenteral antibiotic; X-rays done to classify fractures by Gustillo-Anderson classification. Documented were entry, exit wounds and neurovascular status of the limb. Bone marrow was reamed manually and collected oozing reamed marrow was used as graft. Drain was used minimally and when used, was placed where the reamed marrow would not be drained. Patients were followed-up between one to three years.**
***Mean outcome measure*: Clinical and radiological evidences of healing of the fracture at six weeks.**
***Results*: Patients age ranged between 15-70 years with mean of 32.2±12.2 years. M : F 32:1. Thirty-one (86.1 %) were femoral fractures and 15 (41.7%) of studied long bone fractures were around the knees. The fractures were mainly Gustillo- Anderson type I (41.7%) and II (41.7%). At six weeks there was massive callus formation in 86.1 % of the fractures sites. All other fractures healed within three to four months except one fracture.**
***Conclusion*: Fractures of femur and tibia fractures due to gunshot injury fixed with SIGN intramedullary interlocking nails and grafted with reamed bone marrow give excellent result. This may be due to the use of harvested osteogenic and osteoinductive bone marrow.**

INTRODUCTION

Gunshot injuries are escalating social and medical dilemma in many Western and some developing countries and incidence of gunshot injury is increasing worldwide due to the fact that there is increasing violence in the society (l, 2). The mechanisms of injury are mainly by crushing and stretching of tissue (3), dissipating the kinetic energy of the bullet, shock wave, temporary and permanent cavitation, and secondary missiles (4). The other mechanisms include wadding, yaw or tumbling and characteristics of the bullet and of the tissue through which it travels determine the severity of the gunshot injury (4). ln gunshot injuries, the single most important factor in creating wound is the velocity of the bullet, usually classified as either low velocity (<600m/s) or high velocity (>600m/s) (5). Low velocity wounds are more common in civilian practice and are usually less severe, whereas high velocity wounds are more severe in nature, causing widespread tissue damage, and are more commonly seen in the military setting (5).

The injuries at the extremities might involve complex soft tissues, bone, musculotendinous, vascular and nerve injuries (3). The management of these injuries could be challenging and have become a continuous burden on community and hospital resources around the world (3). Fractures caused by gunshots are becoming increasingly common in urban hospitals and trauma centres (6). When the long bones are involved, the injury results in comminuted open fractures, which pose a challenging problem to orthopaedic surgeons (7). With this increasing gunshot injuries, civilian orthopaedic surgeons

will be required to manage gunshot fractures of the extremities with increasing frequencies, this requires understanding of the principles of ballistic injury and familiarisation with the nature of low and high energy transfer to soft tissue and bone (2). A wide range of methods ranging from non-operative such as 'low-tech' splintage through external fixation (Damage Control Orthopaedic-DCO) to internal fixation or intramedullary nailing has been used (8, 9). Others have combined both the initial external fixation, then followed by intramedullary interlocking nailing (10). Literature review revealed that non-union of long bone fractures caused by gunshot injury ranges from five to eight percent (11,12).

This paper is to present the outcome of comminuted femur and tibia diaphyseal fractures due to gunshot injury grafted with reamed bone marrow, reamed bone particles and immobilised with Surgical Implant Generation Network (SIGN) interlocking nail at three centres. SIGN intramedullary interlocking system is used in treating long-bone fractures by the use of an external jig and slot finder to place the interlocking screws thus imaging systems like C-arm or image intensifier may not be required to achieve this interlocking nailing (13,14). Literature reviewed did not show any previous work on using reamed bone marrow as a graft and "SIGN" interlocking nails to treat long bone fractures secondary to GSI, thus this work.

MATERIALS AND METHODS

This was a prospective study of comminuted femur and tibia diaphyseal fractures secondary to gunshot injury treated with reamed bone marrow, reamed bone particles and SIGN intramedullary interlocking nail at three centres. The study was conducted and approved by the ethical committee or the authority at the three centres from July 2007 to July 2010. Three surgeons operated 33 patients with 36 fractures. The injured patients were resuscitated and stabilised in the Emergency room (ER). Collected information on each patient included age, sex, assailant, presence of exit wounds and interval between injury and presentation in the ER. Neurovascular status of the limb injured was thoroughly examined to record neural and vascular injuries. Anterio-posterior and lateral views plain radiographies of the injured limbs were obtained to determine the fracture pattern. Fractures were subsequently classified using Gustillo Anderson method of classification of open fracture. Irrigation with normal saline under high pressure and initial debridement was done in ER in factures that were Gustillo-Anderson type II and III. All fractures were fixed by open reduction and internal fixation with the SIGN intramedullary interlocking nail. Interval between injury and surgery as well as associated injuries were documented. Intra-operatively, the shells (wad) were removed but the bullets and pellets were only removed if they were encountered along the course of the surgery. There were no deliberate attempts to look for the bullet and the pellets. Bone marrow was reamed manually and the oozing reamed marrow was collected with a dish, bone flute / particles were removed from the reamer and used as graft. At the surgery, the wound was copiously irrigated with normal saline. Drain was used minimally in this study and where it was used, placement was done to avoid drainage of reamed marrow.

Fifteen patients with 19 fractures (52.8%) were operated within five days of injury, ten (27.8%) had surgery between six to ten days and seven (19.4%) had surgery 11-26 days post injury. All the patients had the prophylactic parenteral cefuroxime at presentation and at induction; this was changed to oral for seven days.

Clinical and radiological follow-up of patients were done at out-patient clinic to determine healing at six weeks post-surgery. Infection was documented and follow-up with Complete Blood Count (CBC), Erythrocyte Sedimentation Rate (ESR) and X-rays at every outpatient visit. Patients were followed up between one to three years and three patients with three fractures were lost in early follow-up.

The data obtained were entered into and analysed manually and with Microsoft excel. The level of statistical significance was determined at $p>0.05$.

RESULTS

Thirty-three patients consisting of 32 male and one female with 36 fractures were studied. Their age ranged between 15-70 years with mean age of 32.2 ±12.2 years. Fifteen (45.5%) patients were shot by unknown / armed bandit assailants while sixteen (54.5%) patients were shot by security agents. All patients presented within six hours of injury except a referred case. There were 31 femoral shaft and five tibiae fractures. All fractures were fixed statically, the femur fractures were fixed by retrograde approach in 19 (61.3%) and antegrade approach 12 (38.7%). The time between injury and SIGN interlocking nailing ranged between one day and twenty six days with average of 7.7 ± 6.2days. Thirty-four of the fractures were severely comminuted, one was long spiral fracture and the remaining one was short oblique fracture. None of the patients had injury in any other part of their body but there were two femoral artery injuries. Site of fractures R= 16, L=20.

Table 1
Parts of the bone fractured by the GSI and interlocking nail approach

Bone involved	SIGN Interlocking Nailing	Segment of bone fractured by the gunshot		
		Upper 1/3	Middle 1/3	Lower 1/3
Femur	Antegrade (12)	7	5	0
	Retrograde (19)	1	5	13
Tibia	Tibia (5)	2	3	0

31 (86.1%) fractures were femoral fractures and 15 (41.7%) of the fractures were around the knees.

Table 2
Gustillo-Anderson Classification of fractures and infection

Gustillo-Anderson Classification	Frequency (n)	Infection (n)	
		Superficial(n)	Deep(n)
I	15	0	0
II	15	3	1
IIIA	3	1	0
IIIB	1	0	0
IIIC	2	0	0

Key: f-up= follow-up
Wound infection 13.9 % with superficial infection accounting for 11.1 %

Table 3
Presence of Entry, exit wound (s) and infection

Wound(s)	No of fractures	Wound infection
Entry wound only	23	3
Entry and exit wound	13	2

Chi-square p =0.866 (p>0.05) and it shows that there was no statistical difference in the rate of wound infection between those with entry wounds only and those with both entry and exit wounds.

Figure 1
Good callus formation at the fracture site at six weeks post injury

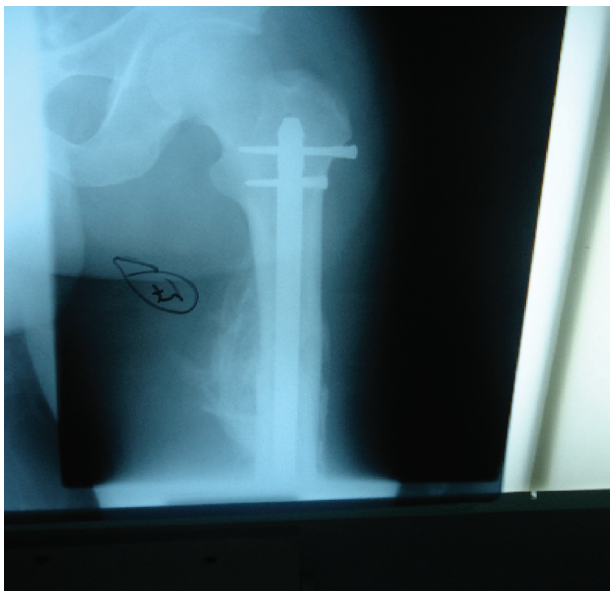

Figure 2(a)
Shows (a) pre-operative X-ray of Gustillo-Anderson Type I, femoral fracture, (b and c) showing post-operative X-rays of the same fracture after SIGN intramedullary nailing

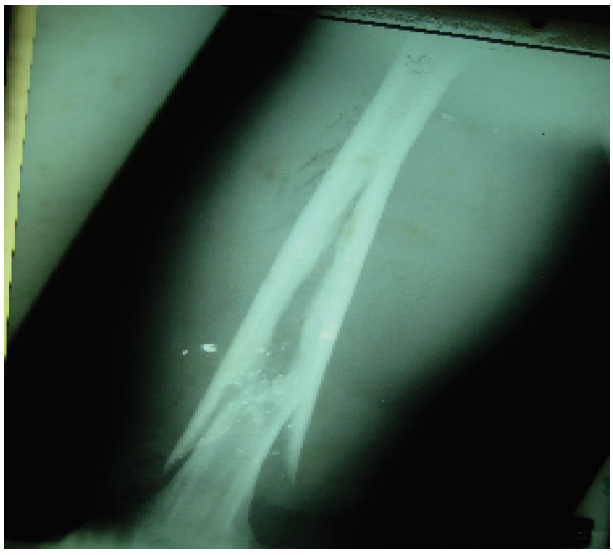

Figure 2(b)

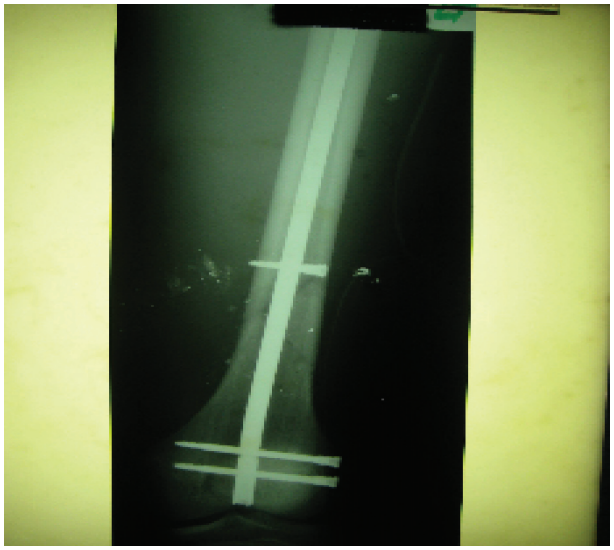

Figure 2(c)

Figure 3(a)
Showing a consolidated fracture of fig. 2 above at nine Months

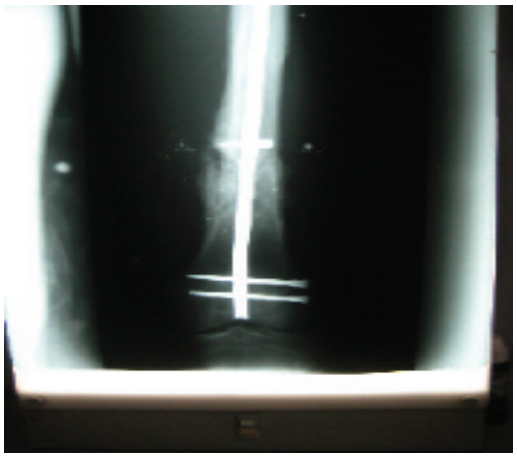

Figure 3(b)

Frequently of wound infection in fractures operated within 0-5, 6-10 and 11-26 days were 3, 0 and 2 respectively. There was a case chronic osteomyelitis with loosen of the distal interlocking screw of the tibia fracture and elevated CBC and ESR. Other complication recorded included limb shortening in a patient. Thirty-one of the fractures (86.1%) showed good callus formation within six weeks of surgery and the fractures healed within three to four months except one fracture with delayed union.

DISCUSSION

Gunshot wounds remain a major clinical problem with bone or joint injuries comprising a major portion of gunshot wound injuries and it is paramount for Orthopaedic surgeons to be thorough in the treatment of patients with these injuries (15). Comminuted fractures due to gunshot injuries are a challenging problem for Orthopaedic surgeons (3). The study show the vulnerability of the productive young males to sustaining femur and tibia diaphyseal fractures from gunshot injuries in the three centres. Despite the high percentage (41.7%) of gunshot injuries around the knee as showed in Table 1, there was no case of popliteal vessels injury unlike in the work done by Burg *et al* in which there were six popliteal artery injuries requiring repair or reconstruction in fractures around the knees. Two cases of vascular injury (femoral artery) were recorded and prompt repair of the this arterial injury was important for the survival of the limbs. The initial assessment of fractures secondary to gunshot injury must accurately document the vascular and neurological status of the limb. It has been reported that successful limb salvage is most dependent on the associated vascular injury while neurological injury is a major determinant of long term-term disability in these type of fractures (16). Aydm *et al* recommend that immediate operative exploration of the extremities in patients with hard

signs of vascular trauma without angiogram, thereby minimising the ischaemic interval (17). Vascular repair was done in the two patients with femoral artery injury without angiogram.

External fixator (DCO) was applied for 21 days in a patient because there were infected multiple entry wounds and multiple pellets around the knee. Open IM nailing was done when the infection was controlled. All the fractures were fixed by open reduction and this afforded the surgeons the opportunity to further debride the gunshot wounds adequately and where necessary to remove the wad. A thorough debridement of the gunshot wounds at the operation time was done and bullets/pellet fragments were removed if encountered in the course of the surgery. Unlike bullet, wad was looked for, located and removed. Mandracchia *et al* stated that a surgeon who believes in wide excision of tissue from all sides of the wound path in any high-velocity wound probably does more harm than that done by the bullet alone (18). They also stated that a surgeon treating gunshot wound victims should follow the dictum: "Treat the wound, not the weapon (18). It is often difficult to locate a lodged wad, its removal is necessary because it can incite a local inflammatory response and harbour bacterial contaminants (19).

The SIGN interlocking nail used in this study has a 0.5mm excursion that allowed for micromovement at the fracture site which make the nail unique compared to other nails. The fractures healed satisfactorily within three to four months and there was no non-union despite the comminuted nature of the fractures and the tissue contusion around the fracture sites.

Bone marrow possess osteogenic and osteoinductive abilities that stimulate healing at the fracture site (20). The presence of the grafted marrow would have contributed to healing of all the fractures by its osteogenic and osteoinductive properties. Other workers have used autologous red marrow to stimulate bone healing of nonunion as a renewable and reliable source of osteogenic stem cells harvested from the iliac crest marrow (20-22). The use of the reamed autologous marrow graft avoided the complications associated with harvesting canceollous bone graft or bone marrow aspiration from the iliac crest. The limitation of using reamed bone marrow is that it cannot be used alone where there is missing bone segment. It may have to be combined with osteoconductive corticocancellous or cancellous bone graft. Another limitation is that only limited quality graft could be obtained from the bone marrow reaming.

Tables 2 and 3 show infection as related to Gustillo-Anderson classification and the presence of entry and exit wounds. Table 3 also revealed that there was no statistical difference in wound infection rates in those with exit and those without, $p = 0.866$. We observed that there was presence of good callus formation as showed in Figure 1 at the fracture sites within six weeks of surgery in 31 (86.1 %). There was appearance of callus or bridging of the cortex with at least partial obliteration of the fracture line in AP and LAT X-ray views as reported by Chao *et a1* (23). Figures 2 and 3 showed the outcome of a patient followed-up for nine months.

The infection rate was 13.9% in which 11.1% was superficial. The only deep infection was a chronic osteomyelitis that occurred in the distal tibia in a patient who had the entry wound on the medial aspect of the leg and this support the statement that "gunshot tibia fractures have an infection rate similar to that of Gustilo lIIb injuries if the entrance is over the medial subcutaneous border of the bone" (24). The cutaneous nature of the distal tibia predisposes the site to infection in gunshot injury.

Timing of the IM nailing seems not to influence the wound infection. Wright *et al* has reported that there were no complications related to immediate internal fixation while Molinari *et al*, reported that operative outcomes with regard to immediate, intermediate, and delayed fixation has no significant differences among the three groups (6, 24). Nineteen patients had retrograde fixation of the fractured femur and the five tibia fractures had IM interlocking nailing with entry point through the knee. Out of these twenty-four patients, 23 (96%) had restoration of normal range for movement of the knee at six months post-surgery with active physiotherapy.

We recorded a delayed union due to early implant failure- brakeage of the two distal locking screws and early immobilisation without crutches, the fractures healed at 15 months post injury.

In this study we found out that thirty-one (86.1%) of the studied gunshot fractures of femur and tibia treated with harvested reamed bone marrow and SIGN intramedullary interlocking nail showed good callus formation at six weeks post-surgery. The outcome may be due to the use of harvested osteogenic and osteoinductive bone marrow.

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