Management of compound subtrochanteric fractures of the femur caused by bullets using an external fixator: A prospective study

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Background
Compound subtrochanteric fractures of the proximal femur caused by bullet injuries are a severe form of injury that are not common, and yet their management represents a major challenge. A specially designed external fixator can be used to treat these fractures, with avoidance of possible complications such as infection or nonunion. The author reviewed his experience with an external fixator in the management of this pattern of fractures.

Aim
A prospective evaluation was carried out of the result of treatment of bullet-caused subtrochanteric fractures by an external fixator.

Patients and methods
During the period between February 2011 and January 2012, eight male patients presented to the Kasr Al-Ainy School of Medicine and New Kasr Al-Ainy Teaching Hospital with compound subtrochanteric fractures of the femur caused by bullets. The patients were between 19 and 48 years of age (mean 33.5 years). All cases were primary fractures. They were followed prospectively after fixation of the fractures using a specially designed external fixator.

Results
The mean duration of healing was 20 weeks (range 18–26 weeks) according to the degree of comminution and soft tissue injury. Three patients developed pin-tract infection that resolved after removal of the frame. One patient developed shortening of about 2 cm. No deformity developed in any patient. No extra measures were needed. At the last follow-up, the results of all cases were scored as good (five cases) to excellent (three cases), with no fair or poor results.

Conclusion
An external fixator can be a reliable method to treat comminuted subtrochanteric fractures caused by bullet injuries.

Keywords:
bullet, compound, external fixator, subtrochanteric

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Introduction

The incidence of bullet wounds among civilians has increased in many parts of the world, sometimes approaching an epidemic level [1].

According to the Gustilo and Anderson classification, fractures caused by missile injuries are considered a special category that is included in type III irrespective of the size of the wound [2,3].

There are many complications with missile injuries such as infection, nonunion, and malunion, especially with associated soft tissue loss or use of open methods of fixation, in addition to social, economic, and psychological factors. Most of these injuries require long-term treatment protocols and care from many medical specialties for the patient to return to a normal or near-normal condition [4].

Subtrochanteric fractures by definition include the area from the level of the lesser trochanter to 5 cm below this level or till the junction between the upper and the middle thirds of the femoral shaft, which is an area of high stress concentration that is more prone to nonunion and delayed union; thus, these fractures are expected to heal between 3 and 6 months, but if the patient still feels pain with weight bearing after 6 months, there may be a possibility of nonunion [5].

Thus, the high possibility of infection after the management of subtrochanteric fractures by internal fixation after a bullet injury, with the risk of nonunion from soft tissue dissection, together with the already present risk of nonunion of these fractures *per se*, can raise the chance to use external method of fixation.

Patients and methods

Patient selection

Between the period of February 2011 and January 2012, eight male patients presented to the Kasr Al-Ainy

School of Medicine and New Kasr Al-Ainy Teaching Hospital with compound subtrochanteric fractures caused by bullet injuries. The patients between 19 and 48 years old (mean 33.5 years) were admitted and managed according to a special sequence.

Clinical evaluation

(1) Resuscitation was performed in the Emergency Department by thorough primary and secondary surveys according to the Advanced Trauma Life Support (ATLS) protocols [6].
(2) Whole-body assessment was performed by a general surgeon, a vascular surgeon, a urology surgeon, and a neurosurgery surgeon organized by the emergency team leader (intensivist).
(3) Limb assessment was performed, with documentation of the vascular state of the limb after stabilization of the general condition of the patient.
(4) Intravenous third-generation cephalosporin (2 g) was administered.
(5) An antitetanus toxoid injection was administered intramuscularly after sensitivity testing.
(6) Blood samples were obtained for laboratory investigations and blood reservation.
(7) Irrigation of the limb wounds was performed with isotonic saline of both the inlet and the exit wounds.
(8) Dressing of the wounds was performed with compression by application of crepe bandage to fix the dressings.

Radiographic evaluation

After stabilization of the hemodynamics of the patient, he/she was transferred to the Radiology Department, where radiography (anteroposterior view of pelvis, anteroposterior view of the upper femur, lateral view of the hip and the upper femur, lateral view of the lumbosacral spine and other areas), abdominopelvic computed tomography, Dopplex, if needed, and cystourethrogram were performed.

Data obtained

The following data were obtained after initial management:

Eight patients had subtrochanteric fractures, and no vascular injury, no compartment syndrome, and no associated sciatic nerve palsy were detected; two patients had soft tissue loss.

Age distribution of the patients ranged from 19 to 48 years (mean 33.5 years) (Table 1).

All patients included in the study had been injured by high-velocity missiles (rifles and guns).

All patients had unilateral injuries: five on the right side and three on the left side.

Six of the eight patients (about 75%) had associated pelviabdominal injuries that required intervention by a general surgeon and/or a urologist.

Operative technique

The following external fixator was used with three sets of Schanz pins: two pins inserted through the head and neck of the femur, two pins inserted immediately below the fracture, and last set included two pins inserted 10 cm below the previous set. A specific joint was used to allow rotation of the joint to accommodate the neck/shaft angle. Two rods were used to augment the frame and all joints were coupled to both rods as shown in Fig. 1.

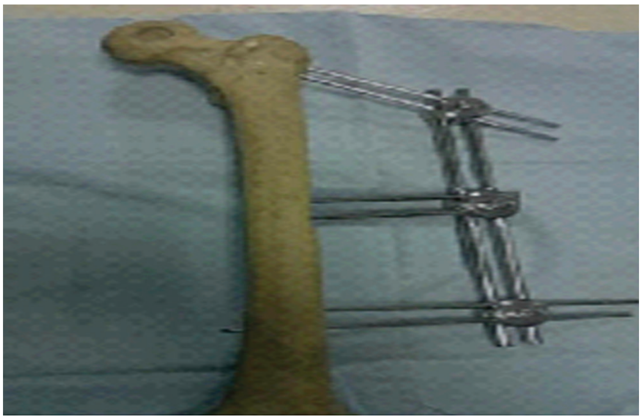
On admission, by surgical or urological operations, debridement of the entrance and exit wounds was performed with extension of the skin wound and removal of dead parts of the subcutaneous and muscle tissue according to muscle viability criteria; the criteria of classic four Cs (color, consistency, contractility, and capillary bleeding) were used and smashed bone particles were also removed [7,8].

The wound was approximated to allow drainage. Skin traction was applied with a weight roughly one-sixth of the body weight. Triple antibiotics were administered (third-generation cephalosporin, gentamicin, and metronidazole drip), and then the patient was

Table 1 Age distribution

Age group (years)	Number of cases
10–20	1
20–30	2
30–40	4
40–50	1

Figure 1



The specially designed fixator used in the study.

transferred to the ICU or the regular ward according to the associated injuries or his/her general condition.

Two patients were managed primarily using an external fixator as no surgical or urological interventions were needed.

After stabilization of the general condition of the patient, which enabled the placement of the patient on a fracture table, anesthesia, usually general because of associated general trauma, was administered. The patient was placed on a fracture table using an image intensifier and closed reduction of the fracture was performed. With the limb held in neutral rotation, two 5 mm Schanz pins were inserted, through stab incisions, into the femoral head from the base of the greater trochanter. Two pins were then inserted at right angles into the femoral shaft beyond the distal limit of the fracture. The other set of two pins was inserted 10 cm below the second set. All the pins were inserted after predrilling and radial preloading was performed. The clamps were tightened and the final position was checked radiologically.

Delayed primary closure or coverage was performed at this stage; two patients only required plastic coverage by the plastic surgeon and good healing of the skin was achieved. Fixation pins were not placed through the wound, but through intact skin and soft tissues.

Postoperative care

Administration of parenteral antibiotics (in the form of third-generation cephalosporin) was continued for an additional 3 days.

Daily pin-tract dressing was performed with alcohol and an antibiotic ointment. Active hip, knee, and ankle exercises were started immediately postoperatively as and when the patient was comfortable. Ambulation without weight bearing with the support of a walker was started according to the patient's condition. The patient was discharged from the hospital once he/she was familiar with exercises, ambulation, and pin-tract care. Partial weight bearing was allowed at the radiological appearance of callus, usually by 10 weeks. The patient could bear full weight on the fractured limb usually between 14 and 18 weeks.

The patients were evaluated at monthly intervals and assessed in terms of range of knee movement, pin-tract infection, pin loosening, and clinical and radiological evidence of union. Upon radiographic and clinical healing, the fixator was removed under inhalation anesthesia.

Functional outcome after healing and full weight bearing was estimated according to the Kyle scale [9] (Table 2).

Results

Fractures were reduced and fixed with a special external fixator in a total of eight patients. The interval from trauma to the final operation varied from 1 to 11 days according to the patient's general condition. Intraoperative blood loss was less than 50 ml in all patients; no blood transfusion was required during the application of the fixator, although six patients required transfusion at admission and during the surgical or the urological intervention. The duration of operation ranged from 35 to 75 min (mean 55 min).

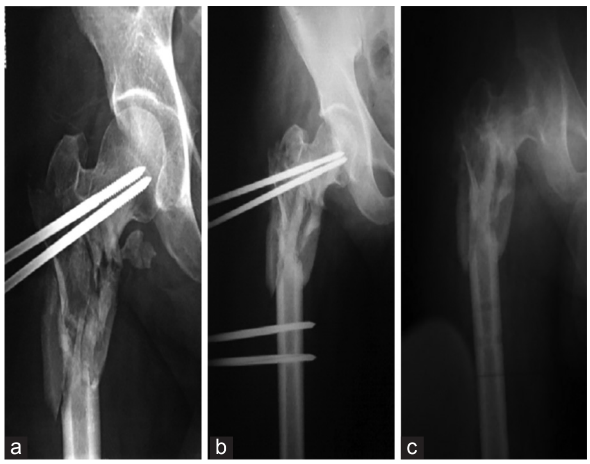
The duration until achievement of full healing with radiographic and clinical signs of healing ranged from 18 to 26 weeks (mean 20 weeks); two patients with soft tissue loss who required a plastic intervention achieved healing at a prolonged duration of more than 20 weeks, but no other bony measures were done. Both patients achieved healing finally (Fig. 2).

Table 2 Kyle scoring scale for hip pathology

Excellent
No or minimal limp
No pain hip joint
Full ROM hip joint
Fair
Limp up to moderate
Moderate pain (using two sticks)
Limited ROM
Good
Mild limp
Mild occasional pain
Full ROM
Poor
Wheelchair bound
Pain on any position
Nonambulatory

ROM, Range of motion

Figure 2



Compound subtrochanteric fracture: (a) at the time of fixation, (b) 10 weeks after injury, (c) after 20 weeks with complete healing and removal of the fixator.

Limited knee motion was encountered in two (25%) patients because of more distal insertion of the pins because of associated soft tissue loss. This distal insertion of the pins led to tethering of the iliotibial tract, which hindered the knee flexion. Range-of-motion exercises were required until they achieved the full range during the follow-up period under the guidance of a physiotherapist.

Three (37.5%) patients developed pin-tract infection, but the overall construct of the fixator was stable because of multiple sites of anchorage to the bone, and the infection resolved with the removal of the frame after complete healing, usually within a couple of weeks.

During the follow-up period, one (12.5%) patient developed shortening of about 2 cm that was compensated by a shoe insert; this patient also had soft tissue loss, but no infection was encountered.

There were no cases of refracture after removal of the fixator. No additional measures such as grafting were needed.

After healing and removal of the fixator, the Kyle scoring system was used in all patients and the following results were obtained: three (37.5%) patients showed excellent results and five (62.5%) patients showed good results. No fair or poor results were obtained on the basis of the criteria of Kyle scoring (Table 3).

Discussion

Open fractures because of high-velocity missile injuries (bullets and shells) are very extensive injuries; there has been an increase in the number of these injuries among civilians because of terrorism. The injuries concomitant with the open fractures have long been considered surgical emergencies [4].

Wound ballistics is the science that studies the effects of penetrating projectiles on the body [10,11]. Velocity and missile mass are considered to be the most significant determinants of tissue damage. Velocity is usually considered to be more important than mass; for example, doubling the mass only doubles the kinetic energy, whereas doubling the velocity quadruples the kinetic energy according to the law kinetic energy=$\frac{1}{2}mv^2$, where m is the missile mass and v is the velocity of the bullet. In reality, it is easier to increase the mass of a bullet than to double its velocity [12].

Table 3 Complications encountered during the study and the final outcome

	N (%)
Limited knee motion	2 (25)
Pin-tract infection	3 (37.5)
Shortening	1 (12.5)
Refracture	—
Extra measures	—
Kyle's scale	
Excellent	3 (37.5)
Good	5 (62.5)

In gunshot wounds, three primary factors – laceration and crushing (permanent cavitation), shock(sonic) waves, and temporary cavitation (stretch) – determine tissue damage. As a low-velocity missile penetrates firm tissue such as muscle, the tissue is crushed and forced apart (laceration and crushing). With high-velocity missiles, shock waves occur and can produce injury in areas distant from the direct missile path. A shock wave is a physical and audible wave created in the air when a bullet travels at supersonic speeds, meaning faster than the speed of sound. The bullet bow shock wave is the result of air being considerably compressed at the frontmost tip of the bullet as it slices through the air. As the bullet moves forward, a broadening wave of compressed air trails out diagonally from the bullet tip. Shock waves are not only transmitted but also reflected from tissue interfaces [12,13]. The crushing of tissue during passage of the bullet is termed permanent cavitation, whereas temporary cavitation is lateral displacement of tissues that are stretched after passage of the bullet. There is a transient increase in results pressure of 4–6 atm for the duration of a few milliseconds. This transient lateral displacement of tissue, such as skeletal muscle, vessels, and nerves, macroscopically appears as blunt trauma. Inelastic tissue, such as bone, may fracture in this area [14].

The extent and shape of this temporary cavity are related to the local transfer of energy (dE/dx). There is a transient low pressure (subatmospheric) as this temporary cavity collapses, which may suck air from both the entrance and the exit and cause bacterial contamination in the wound [8].

Temporary cavitation does not always cause a large zone of tissue damage, and skeletal muscle is relatively tolerant, especially with low-energy transfer, but projectiles that cause a fracture will transfer energy of the order of a few hundred Joules to the bone [15]. The higher bone rigidity compared with skin and muscle produces a greater resistance and results in greater energy transfer, and commonly results in fracture of the bone. Increasing projectile velocity is associated with an increased cavitation and increased fragmentation [16]. Energy lost because of the resistance of the tissue results in the development of compressive loads that radiate away from the projectile tract and can damage tissues (with the formation of a temporary cavity) by accelerating energy transfer to anything in contact with the projectile as it passes through the tissue, which is considered to be the most significant factor in tissue injury from high-energy projectiles [12].

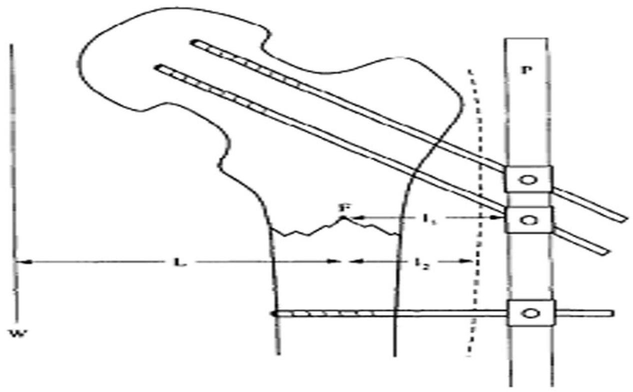
The femur is one of the long bones more frequently affected by gunshots. The thigh is a relatively easy target because of its large size. Inexperienced shooters will attempt to aim for the 'kill zone' (the area of the chest and abdomen) and instead will hit the lower extremities, often the thigh. Typical civilian handgun bullets will strike the femur and often fragment upon impact in the diaphysis and pass through the metaphyseal areas. The stress riser created in the bone cortex leads to a secondary extension to a complete fracture from the combination of weight-bearing forces and muscle contraction, especially during an attempt to 'flee' from the firearm. Another mechanism occurs when the bullet transfers all the energy to the bone and leads to a fracture with significant comminution [17].

The subtrochanteric fractures caused by bullets are not common injuries. In Belgrade, during the period between June 1991 and October 1995, 205 individuals with missile fractures of the femur presented to the Military Medical Academy during the Yugoslavia War. Forty-one (20%) patients had subtrochanteric fractures, of which 29 (15%) patients had fractures caused by bullet injuries, and the remaining 12 had fractures caused by fragments of a mine or explosive devices. Of the 41 patients, 25 were treated by an external fixator [18]. Another series reported on only 17 patients during a similar period of time without distinction between missile and explosive injuries [19]. A series in Kashmir (India) involved 17 patients during the period of January 2005 till March 2007 in a specialized Bone and Joint Surgery Hospital in Srinagar [20].

Subtrochanteric fractures are extremely unstable fractures. Their instability is increased by the presence of multiple bone fragments and in missile fractures by the missile's high kinetic energy, which was the case in the patients. These missile injuries, according to Gustilo *et al.* [21], would be classified from type IIIB to type IIIC.

External fixators have been used by many series to fix subtrochanteric fractures in closed and open modalities of fractures [18–20,22], and proponents of this method have raised the following points: the external fixator augments the physiological stress-reducing effect of the iliotibial tract (Fig. 3). Thus, in unstable situations, the external fixator acts, at best, as a buttressing cantilever. Because of its inherent elasticity, it promotes rapid and exuberant callus formation, thereby enabling load sharing between the fractured bone and the external fixation assembly, which results in a progressive decrease in detrimental stress on the fixation device. Hence, the initial instability at the fracture site is soon overcome [22].

Figure 3



Biomechanics of the external fixator. F, fulcrum; L, lever arm of body weight; l_1, lever arm of the fixator; l_2, lever arm of the iliotibial tract; P, power; W, body weight [22].

Damage control orthopedics is related to the same concept in general surgery, that is, the concept of minimal surgery to stop bleeding and attempt to save lives as hemorrhage is the leading cause of preventable death after trauma, and a strategy to preserve vital functions while preventing further blood loss is an essential first step in damage control. The idea of damage control orthopedics emerged both as an extension of the use of damage control principles in general surgery and as a reaction to the poor outcomes noted with immediate surgery. Studies suggested worsening pulmonary complications in patients with certain lung injury profiles and poor outcomes in patients with severe head trauma following musculoskeletal interventions. Intramedullary nailing of the femur, in particular, became the focus of multiple studies. Larger diameter femoral nails, requiring reaming of the intramedullary canal, are associated with better outcomes than smaller nonreamed nails with respect to union rates, rotational control, and restoration of femoral length. However, it is also well established that opening and reaming of the intramedullary canal releases marrow contents, causing fat embolism in the pulmonary system. These microemboli are considered to cause pulmonary dysfunction by both direct and indirect mechanisms [23].

Better outcome is achieved if conversion of external fixation to nailing is performed within the first 2 weeks after trauma with less tissue damage during nail insertion, but in many situations, the patient's general hemodynamics does not allow for this condition; thus, external fixation as the definitive method of fixation is continued in the patients. Several studies have reported experience in the use of external fixation as a definitive method of fixation with massive war wounds of subtrochanteric and supracondylar femoral fractures. They noted that the final outcome was mainly not because of skeletal injury, but soft tissue damage [18,19,24,25].

In this study, eight patients with compound subtrochanteric fractures caused by bullets were fixed primarily by a special external fixator that allowed multiple points of fixation of the femur. Similar studies have used a special frame; two series used only a femoral fixator, one for closed fractures in Dhal and Singh's [22] series that included 51 patients and one for missile fractures in Nikolic *et al.*'s [18] series, whereas the other used a pelvifemoral fixator in Miric *et al.*'s [19] series.

Healing in this series was achieved in all patients after a period of 26 weeks, whereas in the comparable Dhal and Singh's [22] series, healing was achieved in 24 weeks in most patients and delayed up to 36 weeks in nine patients. In the Miric *et al.*'s [19] series, full healing took 46 weeks, but without distinction between bullet injury and explosive injury. In the earlier Nikolic *et al.*'s [18] series, healing and removal of the fixator were completed in 24 weeks. Therefore, in this series, the healing rate is comparable.

Complications that were reported in this series were as follows: two (25%) cases of limited knee motion that improved after removal of the fixator, three (37.5%) cases of superficial pin-tract infection, but no loosening of the overall frame or deep infection, and one (12.5%) case of shortening, but less than 2 cm, which was compensated by a shoe insert. No pin breakage, deformities, or refracture occurred, but this may be attributed to the limited number of cases.

In the Nikolic *et al.*'s [18] series, deep bone infection developed in three (12%) patients, shortening in one (4%) patient, joint contracture in one (4%) patient, malunion in one (4%) patient, nonunion in four (16%) patients, fixator loosening in two (8%) patients, and refracture in one (4%) patient.

In the Miric *et al.*'s [19] series, deep pin-tract infection developed in one (5.8%) patient that required removal of the frame and traction. Chronic osteitis with fistula and sequestra developed in two (11.7%) patients. Of all distal pins, only one broke and a single proximal pin loosening occurred in three (17.5%) patients. Leg shortening less than 2 cm, because of inadequate reduction, was recorded in three (17.6%) patients. Limitation of hip and knee motion was noted in all patients. The range of knee movement was 80–120° (average 98°) and the range of hip movement was 65–105° (average 98°). There were no nonunions, no refractures, and no late collapse of the fragments [19].

In the Dhal and Singh's [22] series of closed subtrochanteric fractures, three (5.8%) patients showed nonunion that was managed by minimal screw fixation, cancellous grafting, and revision of the fixator. Pin-tract infection developed in 22 (43%) patients. Shortening occurred in two (4%) patients. Refracture occurred in one (2%) patient after fall on a wet floor and this was treated by reapplication of the fixator till healing [22].

Despite the above-mentioned complications, Nikolic *et al.* [18] concluded that the treatment of subtrochanteric missile fractures of the femur represents a complex problem and is associated with a high percentage of complications. External fixation of these kinds of fractures facilitates good access for necessary care and enables early covering of soft tissue defects as well as early physical therapy [18]. Miric *et al.* [19] concluded that pelvifemoral external fixation devices make nursing care much easier, provide stable bone fixation, and enable early patient mobilization. It is obvious that this technique has some specific advantages: versatility in stabilization of this type of fracture, application of the device with minimal operative trauma, and maintenance of access to the wound. This surgical treatment is the optimal method in cases of compound fractures of the proximal third of the femur with extensive soft tissue damage caused by firearms [19].

Dhal and Singh [22] concluded that rigid internal fixation is not the solution to subtrochanteric fractures. However, nonoperative treatment involves prolonged immobilization and its concomitant problems. The overall expenses incurred with the use of either of these conventional methods of treatment place a financial burden on any orthopedic department. The entire process of external fixation, early mobilization, dynamization, and sequential 'build-down', when monitored and instituted at the appropriate time, guided by clinical and radiological indicators of fracture healing, would ultimately lead to the desired biological union, offering a promising alternative in the management of subtrochanteric fractures [22].

Conclusion

On the basis of the principles of Damage Control Orthopedics, an external fixator may be used as an effective method for fixation of compound subtrochanteric fractures caused by bullets. The limitations of this study include the short follow-up period and a small study group; however, long-term results will be reported in the near future.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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