ORIGINAL ARTICLE

Management of Femoral Bone Defect after Gunshot Injury using Circular External Fixator

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ABSTRACT

Objectives: Retrospective evaluation of healing index (HI) and consolidation time (CT) of gunshot femoral bone loss managed using conventional Ilizarov frame (CIF) versus Talyar Spatial Frame (TSF) fixator.

Methods: This multicenter study included 15 patients had gunshot femoral bone loss of about 6 cm and average soft tissue defects of about 7 cm. External fixator was used in 9 patients, soft tissue defect was directly closed in 5 patients, using rotational flap in 5 patients, multiple Z-plasty in 2 patients and in 3 patients soft tissue defect was open managed and closed by secondary intention after application of CIF fixator. CIF fixator was used in 8 and TSF fixator in 7 patients. Mean latency period before starting distraction osteogenesis was 12.8±0.8; range: 12-14 days.

Results: Mean distraction rate was 1.2±0.3 mm/day and inter-fragmentary compression rate was 0.25 mm/day for 5-7 days. Mean consolidation time was 97.8±18.1 days, and all patients had bone lengthening for a mean of 6.4±1.2 with a mean healing index of 15.3±1.37; range: 13.2-17.3. Patients categorized according to type of fixator showed non-significant ($p>0.05$) difference as regards clinical data.

Conclusion: Distraction osteogenesis for gunshot femoral bone injuries could be achieved successfully using either Ilizarov or TSF circular fixator. Both fixators allowed bone lengthening within reasonable CT and with HI of about 15 days/cm.

Keywords: Femoral bone gunshot injury, Distraction osteogenesis, Circular frame fixator, Consolidation time, Healing index

INTRODUCTION

Gunshot wounds remain a major clinical problem [1] and constitute a continuous burden on hospital and community resources [2]. Lower extremity injuries secondary high-energy penetrating injuries caused by suicide bombing attacks [3] or low-energy gunshot wounds are increasingly common in the civilian setting [4].

Gunshot bone or joint injuries comprise a major portion of gunshot wound injuries [1] and severe penetrating injuries caused by a blast may result in severe open limb fractures [3]. Gunshot injuries to the extremities might also involve complex soft tissue, vascular, musculotendinous, and nerve injuries [4]. Management of these injuries is challenging and often requires prolonged and potentially painful treatment [5].

Distraction osteogenesis relies on stimulation of new bone growth so as to provide additional length allowing bridging of bone defects [6]. Whenever, internal fixation of long bone fractures is contraindicated, difficult to achieve, or not advisable, the application of external fixators did well, safely and effectively for management of such cases [7]. Ilizarov technique of bone transport using circular external fixators is widely used for limb reconstruction of large bone defects [5]. The computer-assisted gradual correction with the Taylor Spatial Frame (TSF) is used to correct special orthopedic conditions as delayed fracture healing and pseudarthrosis [8] and is cost-effective methodology for children with unstable tibial diaphyseal fractures when compared to uniplanar frame [9]. Our hypothesis was that the management of femoral bone defect using the conventional Ilizarov frame (CIF) fixator still withstand in front of the Talyar Spatial Frame (TSF) fixator.

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METHODS

This multicenter retrospective comparative study included patients had femoral bone loss secondary to gunshot injury and treated between Jan 2005 and June 2015. The study protocol was approved by the Ethics Committee of Egyptian Alazhar University Hospital. Data were extracted from files of patients signed written informed consent concerning operative procedures to be undertaken and for publication of individual clinical details and accompanying images. Diagnosis was set on the basis of preoperative radiographic and intraoperative findings during the primary treatment.

Collected preoperative data included age, gender, and history of previous 1st aid management at local hospital, its type and outcome. For cases admitted directly to the hospitals included in the study, data included 1st aid management, presence of soft tissue injury and its extent and management, need for blood transfusion for loss compensation or correction of anemia if hemoglobin concentration was ≤9 gm%, the extent of bone loss, presence of associated nerve or vascular injuries. Data of management provided and follow-up data were collected for each patient enrolled in the study separately and then stratified collectively.

Conventional Ilizarov frame was constructed and sterilized preoperatively, to save operative time. Rings of TSF fixator were applied on both sides of injury site and parallel to the in-between joint. Such application site allowed adequate soft tissue cleaning. Three points fixation; 2 proximal and one distal were required for frame fixation. The master tab area of each TSF ring was allowed to be reached for strut applications.

All patients received preoperative prophylactic antibiotics that were continued for 1-week postoperative (PO). PO pain management was started with narcotics on the 1st PO day and oral acetaminophen was used thereafter. Concerning wound management, pin dressing was removed on the 5th PO day to allow daily pin-cleanliness. One-wk after surgery showers were allowed. As regards rehabilitation, patients were asked to start progressive partial weight bearing with crutches since the 2nd day PO and immediate PO quadriceps isometric exercises were initiated to preserve or increase muscle strength. When patient can tolerate range-of-motion knee exercises, it was started.

Post-operative follow-up

Postoperative follow-up included radiological evaluation every 2-wk till defect has been closed. Lengthening was started and continued under weekly clinical evaluation until consolidation occurs and then radiographs are obtained monthly and once tricortical consolidation was developed, as judged by radiographs, frames were dynamized before removal. Preoperative and last follow-up radiographic measurements were reviewed for all patients

Outcome data

Consolidation time (CT) defined as the time (days) between the end of distraction osteotomy and total consolidation or removal of fixator.

The healing index (HI) defined according to Kato 2002 [10] as the time (days) needed for consolidation per cm of distracted osteotomy site (days/cm).

Statistical analysis

Obtained data were presented as mean±SD, minimum and maximum values and numbers. Results were analyzed using Student t-test and Chi-square test (X^2 test). Statistical analysis was conducted using the IBM SPSS (Version 23, 2015) for Windows statistical package. P value <0.05 was considered statistically significant.

RESULTS

The study included 15 patients; male: female ratio was 11:4 and median age was 33 years. Median femoral bone loss was 6 cm and median of soft tissue defect was 7 cm, and 2 patients had associated injury of sciatic nerve. Nine patients had primary external fixation. Soft tissue defect was small and closed by direct closure at time of external fixation in 5 patients (33.3%), another 5 required rotational flap and 2 patients had multiple Z-plasty to achieve direct wound closure. Three patients received open wound management to allow frequent cleasinening and defect edges were gradually approximated during the process of lengthening after application of Ilizarof fixator, thus allowing direct closure by secondary intention (Table 1).

The conventional Ilizarov frame was used in 8 patients (53.3%), while 7 patients (46.7%) had TSF fixation. Irrespective of the applied fixator, small bone defects were compressed, and osteotomy and lengthening were performed at the opposite end of the bone, while in case of large defects simultaneous lengthening and compression was performed and the middle bone segment was transported to fill the defect. Four patients (26.6%) required hydroxyapatite-

coated 6-mm half-pins (Orthofix), while refreshing at the docking site with autologous bone grafting was performed in 6 cases (40%).

Time lag till starting distraction osteogenesis was 12.8±0.8; range: 12-14 days and mean distraction rate was 1.2±0.3; 0.5-1.5 mm/day. Inter-fragmentary compression was performed at rate of 0.25 mm/day for 5-7 days after bone capitation of docking site every 2 weeks for 2 months after consolidation occurred. Fortunately, throughout a mean consolidation time of 97.8±18.1; range: 67-128 days, all patients showed healing with appropriate bone lengthening for a mean of 6.4±1.2; range: 5-8 cm with a mean healing index of 15.3±1.37; range: 13.2-17.3 (Table 2, Fig 1). There was non-significant ($p>0.05$) difference between demographic and clinical data of studied patients categorized according to type of fixator used (Table 3).

Table 1: Demographic and clinical data of studied patients

Patient No	Age (year)	Sex	Side	Soft tissue defects (cm)	Bone loss (cm)	1st aid treatment	Nerve injures	Soft tissue defect closure	
								Procedure	Time
1	27	F	Rt.	10	8	EF	Sciatic	Closure by 2ry intention	Fixator application
2	44	M	Lt.	4	6	EF	-	Direct closure	EF
3	34	M	Lt.	8	7	EF	-	Rotational flap	Fixator application
4	45	F	Rt.	9	8	No	-	Rotational flap	Fixator application
5	33	M	Lt.	4	5	No	-	Direct closure	EF
6	27	M	Rt.	10	8	No	-	Closure by 2ry intention	Fixator application
7	37	M	Lt.	6	7	EF	-	Rotational flap	Fixator application
8	38	M	Rt.	12	8	No	-	Z-plasty	Fixator application
9	25	F	Rt.	3	5	EF	-	Direct closure	EF
10	19	M	Lt.	3	7	No	Sciatic	Z-plasty	Fixator application
11	25	M	Lt.	4	5	EF	-	Direct closure	EF
12	34	M	Lt.	3	7	EF	-	Direct closure	EF
13	27	M	Rt.	10	8	No	-	Closure by 2ry intention	Fixator application
14	45	F	Rt.	9	8	No	-	Rotational flap	Fixator application
15	37	M	Lt.	6	7	EF	-	Rotational flap	Fixator application

Table 2: Healing data of studied patients

Patient No.	Consolidation Time (days)	Bone Lengthening (cm)	Healing index (days/cm)
1	67	5	13.4
2	115	7	16.4
3	95	6	15.8
4	95	6	15.8
5	85	5	17
6	108	7	15.4
7	79	6	13.2
8	118	8	14.8
9	104	6	17.3
10	79	5	15.8
11	85	5	17
12	81	6	13.5
13	113	8	14.1
14	115	8	14.4
15	128	8	16
Mean (±SD)	97.8±18.1	6.4±1.2	15.3±1.37
Minimum	67	5	13.2
Maximum	128	8	17.3

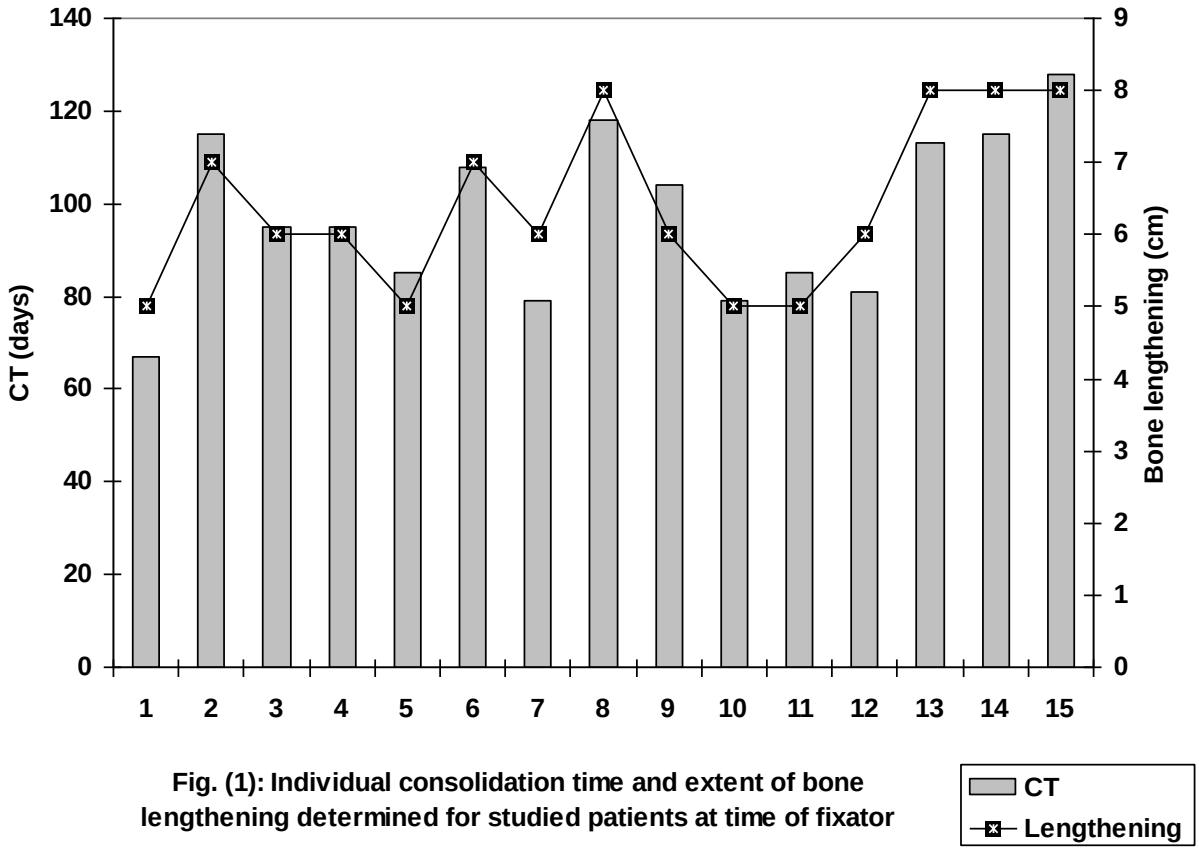

Fig. (1): Individual consolidation time and extent of bone lengthening determined for studied patients at time of fixator

Table 3: Demographic and clinical data of studied patients categorized according to type of used frame fixator

Data & Findings			Conventional Ilizarov frame (CIF)	Talyar Spatial Frame (TSF)
Number (%)			8 (53.3%)	7 (46.7%)
Age (year)			31.1±7.7	35.1±8.5
Sex; M:F			1:7	3:4
Right: left side ratio			4:4	3:4
External fixation at 1st aid treatment			3 (37.5%)	5 (71.4%)
Nerve injures			1 (12.5%)	1 (14.3%)
Bone loss (cm)			6.2±1.3	5.7±1.3
Soft tissue defects	Length (cm)		7±3.5	6.4±2.9
	Procedure	2ry intention	3 (37.5%)	0
		Direct closure	2 (25%)	3 (42.9%)
		Flap	1 (12.5%)	4 (57.1%)
		Z-plasty	2 (25%)	0
Latency period before distraction osteogenesis (days)			13±0.9	12.6±0.5
Distraction rate (mm/day)			1.1±0.4	1.3±0.2
Consolidation Time (months)			3.14±0.64	3.4±0.57
Bone Lengthening (cm)			6.38±1.19	6.86±0.9
Healing index (cm/month)			2.05±0.2	2.03±0.14

Data are presented as numbers & mean±SD

CASE PRESENTATION

Fig. 1: Preoperative Plain X-ray right femur, Female, 25 years old femur fracture gunshot, 32 C31, Gustilo IIIA.

Fig. 2: Plain X-ray right femur, emergency treatment by temporary external fixator in order to damage control strategy

Fig. 3: Plain X-ray right femur. Due to infection, soft tissue and bone necrosis, treatment by washing of body tissues and damaged tissue debridement, application of a new unilateral external fixator.

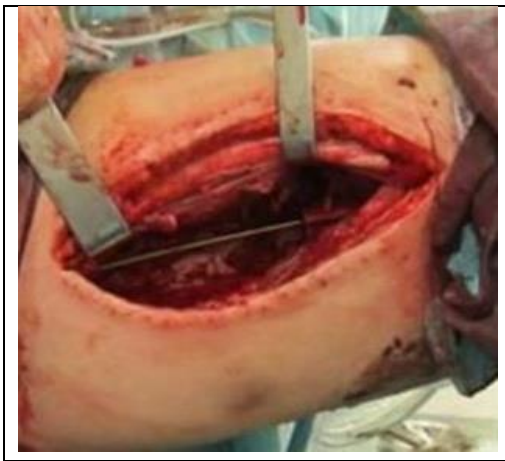

Fig. 4: Intraoperative photo showing treatment by bone resection

Fig. 5: Plain X-ray, anteroposterior view, application of Ilizarov fixator and TSF.

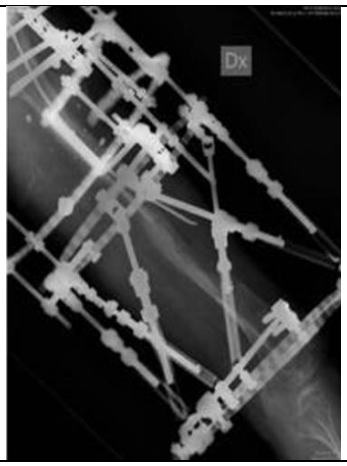

Fig. 6: Plain X-ray, lateral view, application of Ilizarov fixator and TSF.

Fig 7: Plain X-ray, antero-posterior view, application of Ilizarov fixator and TSF. Complete united doking site and complete consolidation of lengthening of site.

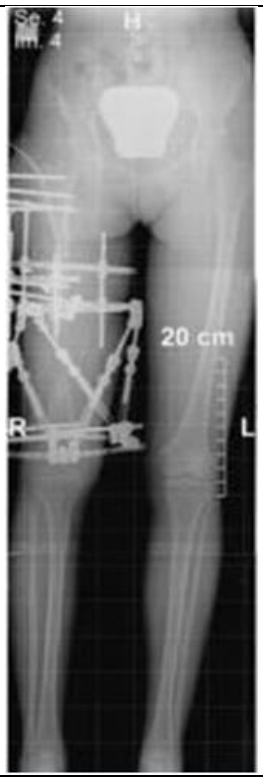

Fig. 8: Long standing file x-ray

Fig. 9: Picture of patient in frame.

Fig. 10: Plain X-ray, antero-posterior view, 7 months after removal fixator.

Fig. 11: Plain X-ray, lateral view, 7 months after removal fixator

Fig. 12: Pictures of patient after removal fixator showing good function of knee joint.

DISCUSSION

This retrospective study illustrated the outcome of the applied policy for management of femoral bone gunshot injury using a graduated program of wound cleansing, debridement, removal of bone debris and foreign bodies with systemic broad spectrum antimicrobial therapy and external fixation for a short time (12-14 days) to allow patients to bypass the post-injury catabolic stage, be generally fit for major surgery and to allow subsidence of tissue edema and local inflammation. Similarly, Patil 2016 [11] found early administration of intravenous antibiotic coupled with early irrigation and debridement dramatically decreases the infection rate of open fractures and Simons 2016 [12] also reported that timing of definitive fracture management has varied from several weeks to within hours of injury.

Soft tissue management of studied patients varied according to the extent of tissue loss and possibility of direct closure, or need for plastic surgery; such policy goes in hand with Barwick & Montgomery [13] and Lowenberg 2013 [14] who documented that optimizing the host environment with eradication of infection by radical debridement, soft-tissue flaps when necessary and bone transport techniques can allow salvage a useful limb in patient had bone and soft tissue loss with infection,

Application of Ilizarov frame fixator allowed soft tissue defect closure and healing by secondary intention during bone lengthening process. In line with these findings, multiple studies previously assured that the Ilizarov technique with bone transport can very successfully deal with the associated large soft-tissue and bony defects without the use of routine bone-grafting, or soft-tissue flaps [15,16,17,18,19,20,21]. Recently, in 2017, El-Alfy [22] found that Ilizarov method in management of cases with bone loss, soft tissue loss and infection allowed eradication of infection in all cases and all soft tissue defects healed during bone transport.

All patients underwent distraction and inter-fragmentary compression; such policy allowed bone defect closure after mean consolidation time of 97.8 days with mean bone lengthening of about 6.4 and mean healing index of 15.3 day/cm. These data indicated the applicability of such management policy for patients with femoral gunshot bone defect and go in hand with that previously reported for long bones lengthening for varied disease conditions where Sala 2013, [23] found primary and definitive fixation with the TSF is effective for management of lower extremity long-bone fractures especially in patients with multiple traumatic injuries. Also, Ajmera 2015 [24] reported mean union index of 74.5 days/cm within a mean union time of 52 weeks for open fractures of tibial diaphysis and concluded that limb reconstruction system for treatment in cases of open fractures with bone loss was effective as definite modality of treatment. Furthermore, Pallaro 2015 [25] reported a mean transport of 41.2 days/cm in patients with infected

femoral bone loss with bone lengthening using external fixator and concluded that the use of external fixation is efficient and provides bone union, treatment of infection, and control of bone axes and lengths.

Moreover, O'Neill 2016 [7] detected excellent results for complex lower extremity long bones fractures treated in a TSF frame. Also, Henderson 2015 [26] and Khunda 2016 [27] documented that the use of the TSF for treatment of tibial shaft fractures has a number of technical advantages while producing good functional and surgical outcomes. Fürmetz 2016 [28] reported an average healing index of 44.2 days/cm for reconstructed tibial defects after a mean consolidation time of 113 days and Aktuglu 2016 [29] using Ilizarov frame detected solid bone formation in tibial bone defects >5 cm after a mean duration of 275.5 days with a mean external fixator index of 52 days/cm and bone union was obtained in 95.8% of patients. Recently, Chou 2017 [30] documented that in treatment of chronic femur osteomyelitis, Ilizarov distraction osteogenesis followed by intramedullary nailing was safe, successful and allowed for union, realignment, reorientation, and leg-length restoration.

The reported non-significant difference regarding outcome including CT, extent of bone lengthening and healing index between patients managed using Ilzarov versus TSF frame coincided with other studies compared both frames where Menakaya 2014 **[31]** reported that despite the assumption of the rigid construct of the TSF, the median time to union was similar to that of the Ilizarov frame, but TSF can play a significant role in complex tibial fractures and Tafazal 2014 [32] documented that in an appropriate patient, both types of circular fixator are equally effective but TSF allows for postoperative deformity correction. Recently, Reitenbach 2016 [6] compared Ilizarov versus TFS for deformity correction and extremity lengthening in the lower leg and found TSF ring fixator leads to fewer problems, secondary axial translations, and pin infections, but is associated with PO deterioration in mobility in the upper and lower ankle joint. However, Mayer 2016 [33] found both Ilizarov and TSF are viable treatment options for infantile and adolescent Blount disease, with the ability to significantly improve mechanical axis of the affected tibia and the limb.

CONCLUSION

Distraction osteogenesis for gunshot femoral bone injuries could be achieved successfully using either Ilizarov or TSF circular fixator. Both fixators allowed bone lengthening within reasonable consolidation time and with healing index of about 15 days/cm. Ilizarov frame allowed soft tissue defect closure without the need for plastic surgery. These results allowed recommending the use of Ilizarov especially in patients with extensive soft tissue defect and whenever plastic surgeon is unavailable.

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