



Treatment of open intraarticular distal femur fractures by Ilizarov fixator; an approach to improve the outcome with mid-term results

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ABSTRACT

Purpose: Open comminuted intraarticular distal femur fracture represents a formidable challenge for the orthopaedic surgeon for the inherent fracture complexity, soft tissue damage, and contamination. The purpose of this study was to evaluate the mid-term outcome results and safety of using the Ilizarov fixator to treat these fractures.

Patients and Methods: The study included 22 fractures treated by debridement with reduction and stabilization by Ilizarov external fixator. The mean age was 35 years. Gustilo grade of open fracture was III-A (19 cases), III-B (2 cases), and III-C (1 case). Six fractures were AO-OTA type 33C2, and 16 cases were type 33C3. Eight patients had associated injuries. Bone and functional results were evaluated by Association for the Study and Application of the Method of Ilizarov (ASAMI) criteria, and Neer knee score. The statistical analysis was done using the IBM SPSS Statistics for Windows.

Results: Seven cases had autogenous bone grafting. The frame crossed the knee in 8 patients. The fixator was removed after a mean of 7 months with union in all cases, and without any malalignment $>5^\circ$. Deep infection occurred in two cases. Quadriceps-plasty was needed for 3 cases. After a mean of 44 months, the last follow-up results showed full knee extension and a mean flexion of 107.59° . The ASAMI functional and bone results were good to excellent in all cases. Neer knee score averaged 86.59.

Conclusions: Ilizarov fixator was an effective treatment modality of open comminuted distal femur fractures with high union rate, adequate alignment and satisfactory functional outcomes.

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Introduction

Distal femoral fractures (DFF) are rare representing about 4–7% of all femoral fractures in adults. Open fractures comprise approximately 10% of these fractures [1]. Every open comminuted intraarticular fracture represents a formidable challenge for the orthopaedic surgeon owing to the inherent fracture complexity with comminution and intraarticular extension. Open DFF pose additional difficulty by associated extensive soft tissue damage, extensor-mechanism injury, and the wound contamination. Moreover, the outcome is unsatisfactory in many cases with frequent complications such as compromised knee range of motion (ROM), implant failure, malalignment, nonunion, and infection. These complications are more frequent with open fractures [2–6].

The relative rarity of open comminuted DFF with considerable diversity of fracture patterns makes it arduous to establish a standard treatment protocol [1]. Variable fixation modalities are available including different plate and screws constructs, intramedullary nailing, and external fixators [7]. The high risk of infection, further damage to the soft tissues by the surgical exposure, frequently-contused soft tissues covering the implant, and the long operating time may preclude ORIF as a safe treatment method [8,9]. Being the workhorse for skeletal stabilization in open fractures, external fixation is a reasonable treatment option for these fractures for avoiding metal implants in the fracture, and percutaneous application. The Ilizarov circular fixator provides adequate biology by percutaneous fixation without soft tissue stripping and an appropriate mechanical environment with high stability allowing early weight-bearing with functional limb use. Ilizarov fixator provides adequate stabilization, and the tensioned thin wires provide adequate purchase of the small fragments [10–12]. Yet, it is disadvantaged by complexity of application, pin track infection, risk of neurovascular injury, and a bulky frame requiring care [12–14]. Moreover, circular fixators are considered to have a limited role in the treatment of acute DFF. Their use is infrequent because

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of the soft tissue tethering, impeded soft tissue access in open fractures, and the need for expertise in application [15].

The purpose of this study was to evaluate the radiographic, clinical, and functional outcomes, as well as the safety of using the Ilizarov circular fixator to treat open comminuted DFF with an approach to reduce its known complications such as knee stiffness and malunion, and to report the mid-term results.

Patients and methods

This prospective study was conducted after approval of the Ethics Committee of the University Hospital. According to Gustilo and Anderson classification [16], and AO/OTA classification [17], the inclusion criteria included open (grade III) comminuted (AO/OTA types 33C2 and 33C3) fractures, in patients older than 18 years, for treatment by Ilizarov external fixator with a minimum follow-up of two years. Exclusion criteria included closed DFF, pathological fractures, neglected or non-united DFF, and patient who did not complete the minimum follow-up.

Initial standard trauma resuscitation and thorough clinical and radiographic evaluation was performed for full assessment of the patient, injuries, and the neurovascular status. Standard radiographs and CT scans with 3D reconstructions were obtained for fracture identification and preoperative planning. Arteriography was done in three cases for vascular assessment. On admission, emergency irrigation and debridement of non-viable and grossly contaminated tissues was performed with administration of intravenous antibiotics, and tetanus prophylaxis. Four cases had infected wounds that were swabbed for culture and antibiotic sensitivity. A combination of cephalosporin and aminoglycoside was administered for three days, followed by the cephalosporin alone. Metronidazole was given when suspecting anaerobic contamination. According to the antibiotic sensitivity results, the regimen was changed when needed.

The study included 22 fractures treated between September 2012 and January 2016 with a mean age of 35.14 (Range 19–47; SD

7.22) years. Four patients were females (18.2%), and 18 were males (81.8%). Left side was affected in 12 cases (54.5%), and 10 (45.5%) were in the right side. The initial mechanisms of trauma were motorcycle accident (15 cases; 68.18%), work-related injuries (4 cases; 18.2%), and gunshot injuries (3 cases; 13.6%). The duration from injury to the definitive surgery averaged 5.18 (Range 1–15; SD 3.92) days. The grade of open fracture was III-A (19 cases; 86.4%), III-B (2 cases; 9.1%), and III-C (1 case; 4.5%). Six fractures (27.3%) were AO-OTA type 33C2, and 16 cases (72.7%) were type 33C3. Associated injuries occurred in 8 patients (36.4%) (Table 1). Initial monolateral fixator was applied in another hospital in 4 cases including one case with associated ipsilateral fracture neck femur treated by cannulated screws. Another case had initial monolateral fixator stabilization for a type III-C open fracture with vascular repair.

The definitive surgery was done after stabilization of the patient's general condition and optimizing the comorbidities. Informed consent was obtained from all patients after explaining the procedure, and stressing on the importance of keeping on smoking cessation and good blood sugar control.

Surgical technique

After spinal or epidural anaesthesia, the patient was placed supine on traction table to restore length, improve alignment, help reduction by ligamentotaxis, and facilitate access to all aspects of the thigh with easier frame assembly. Following meticulous debridement and irrigation a full ring was fixed to the proximal tibia by one wire and a Schanz screw to facilitate traction and reduction. Initial exposure and reduction of the distal condylar fragments was done under fluoroscopic control through the traumatic wound with minimal extension if needed. Reduction was facilitated by an occasionally small medial parapatellar incision, large reduction clamps, or using a pin as a joystick. The initial articular reconstruction was percutaneously fixed by one or two lag screws. Then, the distal recurvatum deformity was corrected by one or two carefully inserted

Table 1
Patients' demographics.

Pt	Age	Gender	Side	Smoking	Co-morbidity	Associated injuries	Injury duration	AO/OTA type	Gustilo grade
1	36	M	Rt	No	HTN	Vascular repair	10 days	C3	III-C
2	47	M	Rt	Yes	DM	-	3 days	C2	III-A
3	40	M	Rt	No	DM	Ipsilat *Fr patella *Common peroneal palsy	15 days	C3	III-A
4	36	2	Lt	No	-	-	3 days	C3	III-A
5	27	M	Rt	No	-	-	1 day	C2	III-A
6	42	2	Lt	Yes	DM	-	5 days	C3	III-A
7	34	M	Lt	No	-	-	2 days	C3	III-A
8	19	M	Lt	No	-	Ipsilat Fr neck femur	10 days	C3	III-B
9	38	M	Rt	No	-	Contral Fr tibia	7 days	C3	III-A
10	45	M	Rt	Yes	HTN	-	5 days	C2	III-A
11	29	M	Lt	No	-	-	3 days	C3	III-A
12	34	2	Rt	No	-	Ipsilat tibial plat	4 days	C3	III-A
13	23	M	Lt	No	-	Ipsilat *Open patellar tendon tear *Open metatarsal Fr	3 days	C3	III-A
14	37	M	Lt	Yes	-	Contral Colles' Fr	13 days	C3	III-B
15	33	M	Rt	Yes	-	-	3 days	C3	III-A
16	35	M	Rt	No	-	-	2 days	C3	III-A
17	42	M	Lt	Yes	HCV	Ipsilat tibial plat and pilon Fr	8 days	C2	III-A
18	45	2	Lt	No	DM	-	3 days	C2	III-A
19	32	M	Lt	No	-	-	1 day	C3	III-A
20	26	M	Lt	Yes	-	-	2 days	C3	III-A
21	34	M	Lt	Yes	-	-	3 days	C2	III-A
22	39	M	Rt	No	HCV	-	8 days	C3	III-A

Pt (Patient), M (Male), F (Female), Rt (Right), Lt (Left), HTN (Hypertension), DM (Diabetes mellitus), HCV (Hepatitis C virus), Ipsilat (Ipsilateral), Fr (Fracture), Contral (Contralateral), plat (plateau).

anterior to posterior Schanz screws, then moving their free ends distally (Fig. 1).

A carbon-fibre ring was anchored to the distal femur by opposing olive wires and, if applicable, one 6 mm-Schanz screw dropped at another level. The crossing angle between the wires was about 70°. With significant comminution precluding adequate purchase of half pins, four wires were used. Then, a full ring with an arch was fixed to the proximal femoral segment by four or five 6 mm-Schanz screws. Frame assembly was completed by connecting rods. Wires and pins insertion was done with the knee flexed about 45° with soft-tissue release around the pins and wires with a haemostat to reduce tethering. The knee ROM was checked.

The final reduction was checked again with image intensifier. The anteriorly inserted distal Schanz screws were removed. The proximal tibial ring was also removed, except when indicated by severe comminution or associated knee injuries (Figs. 2 and 3). Finally, associated injuries were addressed in the same setting including repair of the quadriceps muscle and patellar tendon, intramedullary nailing of tibial fractures, pilon fracture fixation, and Colles' fracture pinning (Table 1).

Postoperative care

Foot-touch ambulation with supervised physiotherapy program was initiated on the second postoperative day. The patients were followed-up weekly till wound healing. Radiographs were obtained in the first postoperative day, every 2-weeks for one month, then monthly till fixator removal. In follow-up visits, the patients were checked for wound status, pin site care, fixator stability, maintenance of reduction and alignment, ROM, and progression of heal-

ing. Fine adjustment of any residual postoperative malalignment was done using a distractor and hinges between the distal femoral ring and the proximal part of the femoral frame. The hinges were replaced by rods after correction. Weight-bearing was gradually increased with progression of union. Fixator removal was done after achieving solid union evidenced clinically by full painless weight-bearing, and by bridging callus in the standard radiographs with obliteration of the fracture lines.

After frame removal, the follow-up was done every three months for one year, followed by yearly visits. Assessment of the bone and functional results was performed according to ASAMI criteria (Association for the Study and Application of the Method of Ilizarov) [18]. Additional functional assessment was done by Neer knee score (excellent ≥ 85 , good = 70–80, fair = 55–70, and poor <55) [19]. The safety parameters included intraoperative and postoperative complications such as blood loss, iatrogenic neurovascular injuries, bone-graft donor site complications, infection, and deep vein thrombosis (DVT). The descriptive analysis and statistical analysis were done using the IBM SPSS Statistics for Windows, Version 22.0 (IBM Corp., Armonk, NY, USA). Level of significance was set at $p < 0.05$.

Results

The mean intraoperative blood loss was 334.1 ml (Range 200–600; SD 109.53). The patients were discharged after an average hospital stay of 10 (Range 7–14; SD 2.02) days, and followed-up for a mean of 44.32 (Range 24–63; SD 10.93) months. Extending the frame across the knee was needed in 8 cases (36.4%), and was removed after 4–5 weeks. Autogenous iliac cotico-cancellous

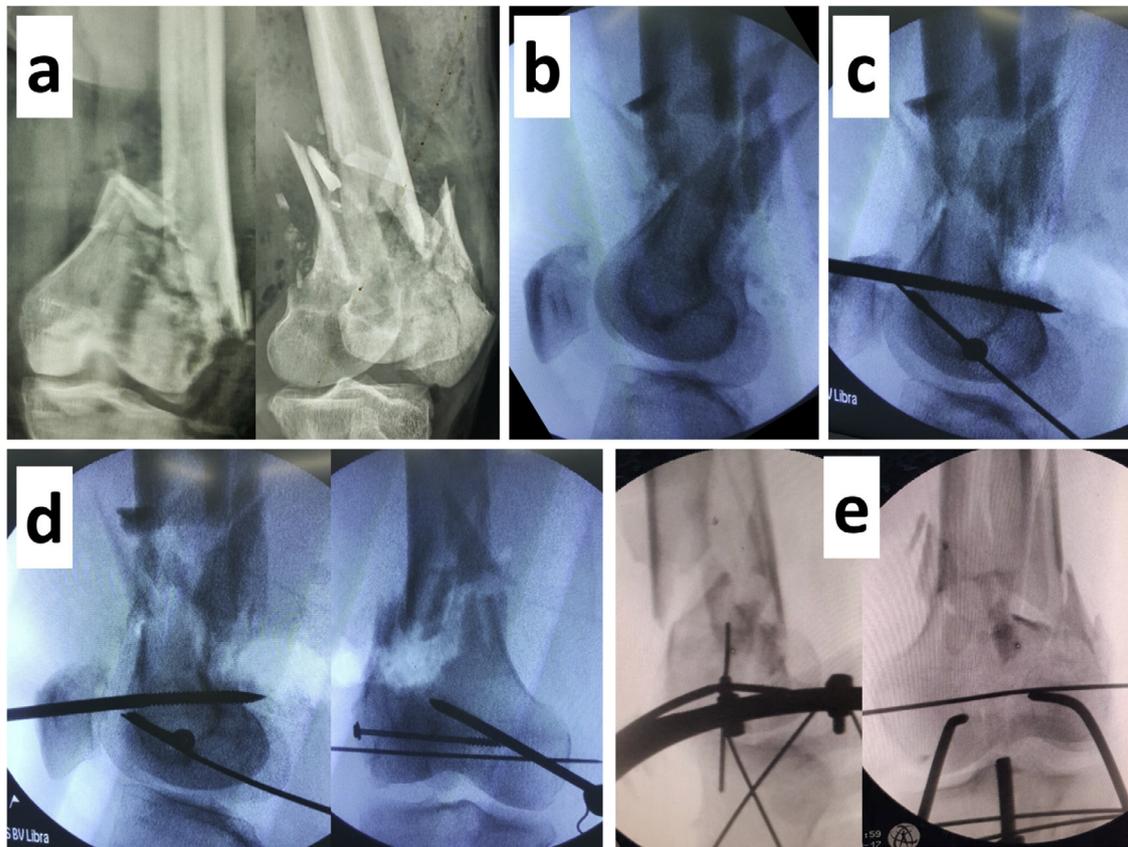


Fig. 1. Reduction of recurvatum deformity of the reconstructed condyles. (a) Preoperative radiographs of 33C3 fracture. (b) Following ligamentotaxis by traction table, a screen-shot of the image intensifier showing the recurvatum deformity. (c) After fixing the condyles with a percutaneous screw and one wire, an anteriorly inserted Schanz pin is tilted and showing partial correction. (d) Lateral and anteroposterior views showing deformity correction. (e) Two Schanz pins used in another case for comminution to have equal forces on both condyles. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

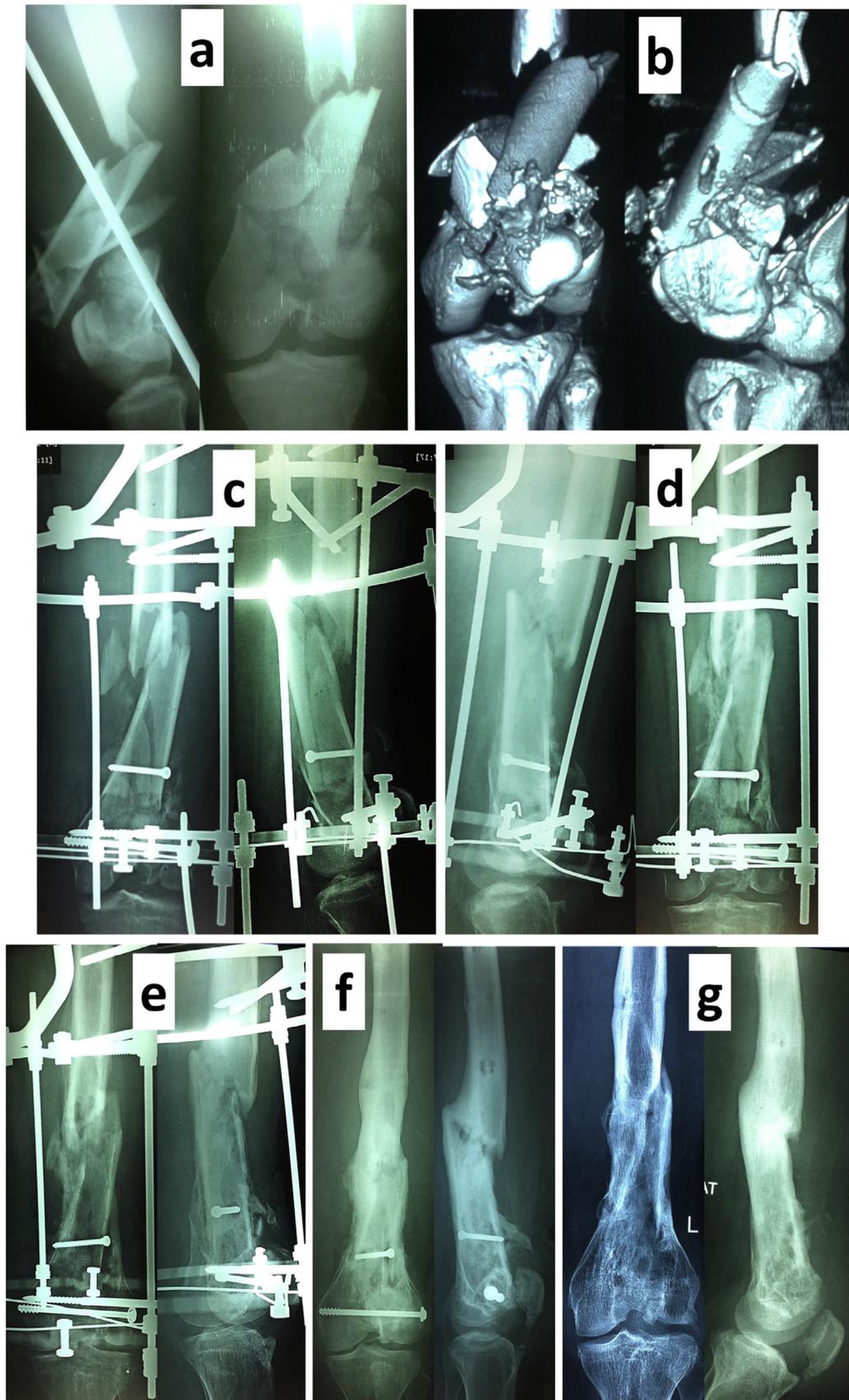


Fig. 2. (a) Preoperative radiographs of 33C3 fracture. (b) 3-D reconstruction of CT-scans. (c) Postoperative radiographs showing Ilizarov fixation, lag screws, and crossing-knee fixation for comminution and patellar tendon laceration. (d) After tibial ring removal and progression of healing. (e) Sound union before fixator removal. (f) Two months after frame removal with anterior callus adhesion to the quadriceps muscle. (g) Four years-follow up radiographs after quadriceps-plasty and screws removal.

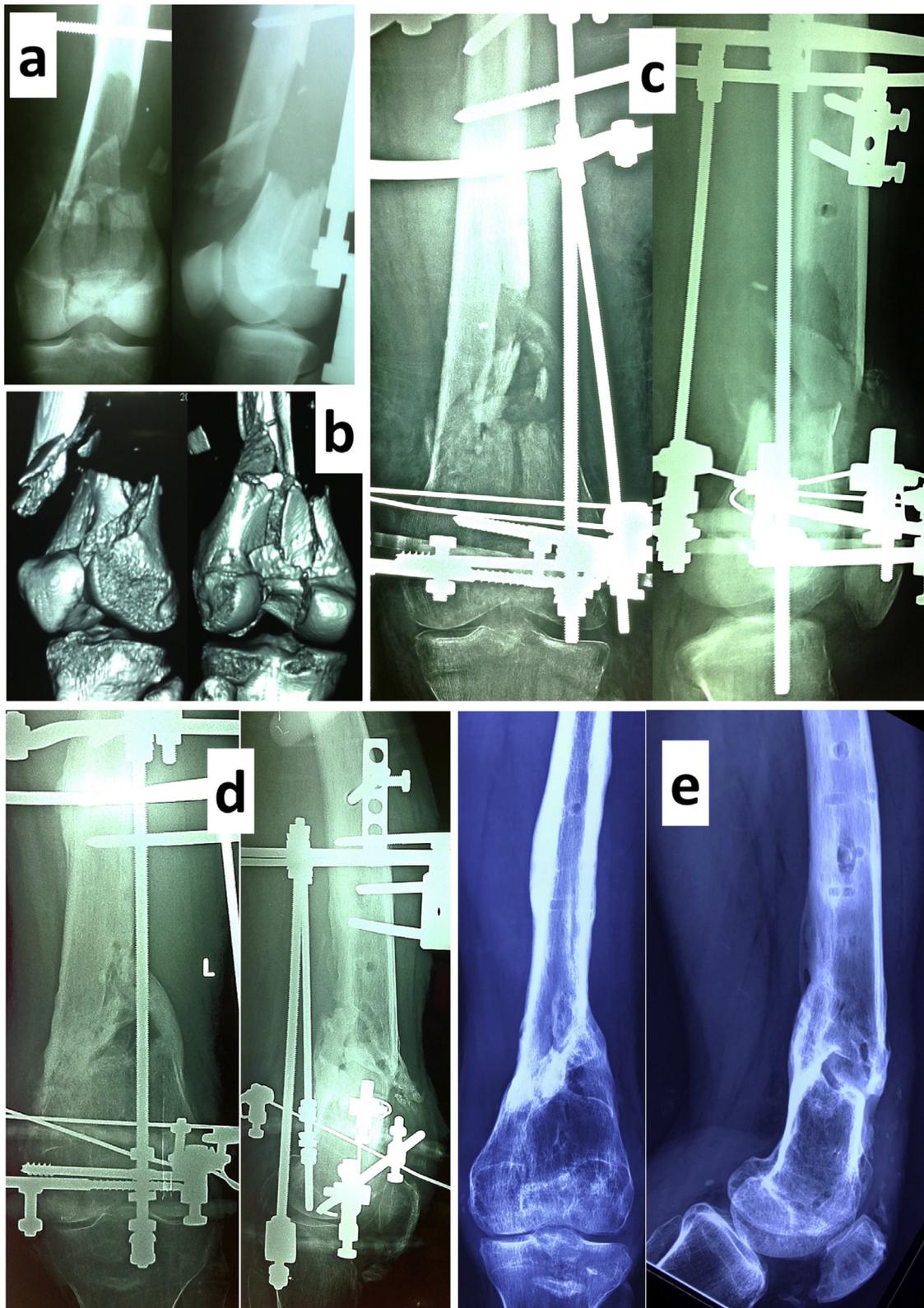


Fig. 3. (a) Preoperative radiographs of 33C3 fracture. (b) Articular comminution seen in 3-D reconstructed CT-images. (c) Postoperative radiographs without across-knee fixation. (d) Radiographs with solid healing before fixator removal. (e) Radiographs at 61 months showing relative narrowing of the joint space.

bone grafting was done in 7 cases (31.8%) to fill a partial bone defect caused by debridement. No case had extensive bone loss necessitating bone transport. The fixator was removed after a mean external fixation period (EFP) of 7.05 (Range 5.5–8.5; SD .94) months with successful union in all cases and without any malalignment $>5^\circ$, significant shortening (more than 2.5 cm), or refracture.

Two cases had 1 cm translation. Four patients had shortening of 1 cm ($n=3$), and 1.5 cm ($n=1$). Soon after Ilizarov fixator removal, knee flexion ROM averaged 66.36 (Range 50–85; SD 10.93) degrees. All cases showed improvement in ROM with supervised physiotherapy except 3 cases required quadriceps-plasty with release of quadriceps adhesions to the distal femoral callus. Using Students t-test, the last follow-up ROM showed significant improvement ($p=.000$) with a mean flexion of 107.59 (Range 70–140; SD 17.32) degrees (Fig. 4). Flexion ROM of 100° or more was achieved in 16 cases (72.7%), 90° – 95° in four cases (18.2%), and less than 90° in two cases (9.1%). All patients had full knee extension. The last follow-up radiographs of two cases (at 61, and 63 months) showed osteoarthritic changes.

Six patients had intermittent pain or with fatigue. Four patients changed their work. One patient had only light work. The remaining 17 patients (77.3%) returned to pre-injury work. ASAMI bone results were excellent in 20 cases (90.9%), and good in the two (9.1%) cases with deep infection. The ASAMI functional results were excellent in 9 cases (40.9%), and good in 13 cases (59.1%) secondary to the reduced knee motion and/or the noticeable limp.

Based on the parameters of the Neer score including pain, function, knee ROM, working ability, gross anatomy, and roentgeno-

graphic findings with the six sub-grading of each, Neer knee score averaged 86.59 (Range 56–100; SD 10.24) with 13 excellent, 8 good, and 1 fair grades (Table 2). This fair grade (case number 4) was due to the combination of fatigue pain, occasional cane use, 70° ROM, changing to light work, and 1 cm residual displacement. There was a significant correlation between the ASAMI functional grade and the Neer score ($p=.000$; Spearman's $\rho=.763$) and its grade ($p=.016$; Spearman's $\rho=.506$).

Complications

Pin track infection occurred in 8 patients, and managed by pin site care with oral antibiotics. One pin was changed in 2 patients (one for septic loosening, and another for pin breakage). Deep infection occurred in two cases (9.1%). Both were controlled by debridement and lag screws removal. One patient developed patella baja following repair of concomitant patellar tendon laceration. He was one of the cases who got ROM improvement after quadriceps-plasty. The 3 cases quadriceps-plasty had mild weakness (grade 4 of 5 muscle power) of the extension power, but none had an extension lag. None had iatrogenic neurovascular injury, DVT, or bone-graft donor site complications.

Discussion

Comminuted DFF are difficult to treat with no consensus on the best treatment modality [20]. Open fracture care with early skeletal fixation removes nidus for infection, and halts the cycle of injury [21]. Most studies are heterogeneous including both open

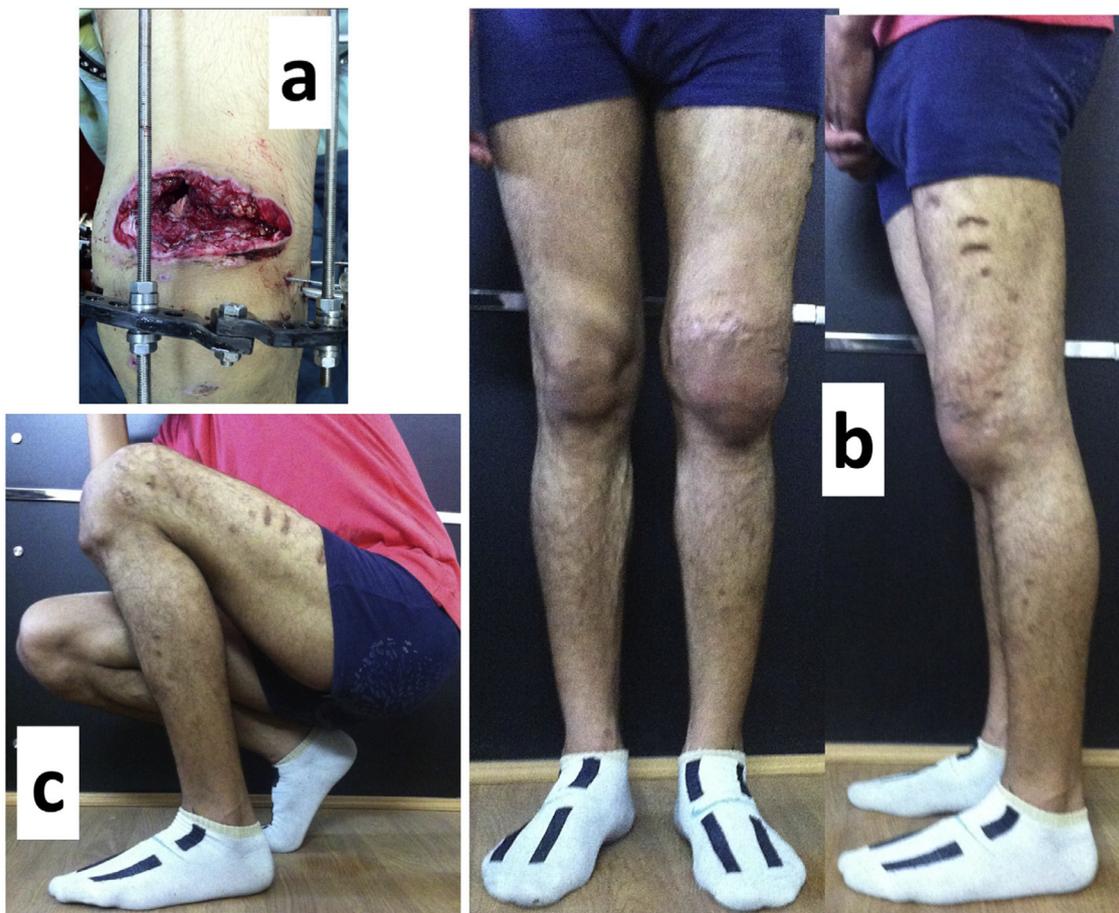


Fig. 4. Clinical photos; (a) Traumatic wound after debridement and frame application. (b) Front and side views of the patient showing scar of the wound in (a) with good alignment, and full extension. (c) Side view showing good flexion motion.

Table 2
Patients' results.

	Blood loss (ml)	Hospital stay	Across knee frame	EFP (mons)	Bone graft	Follow-up (mons)	Post-removal flexion ROM	Last flexion ROM	ASAMI results		Neer score	
									Bone	Func	Score	Grade
1	200	9	No	7	-	40	50°	80°	E	G	72	G
2	250	12	Yes	7	Yes	24	60°	90°	G	G	74	G
3	300	11	No	8	-	39	55°	95°	E	G	86	E
4	350	10	No	7.5	-	62	65°	70°	E	G	56	F
5	500	13	No	6	-	36	75°	120°	E	E	94	E
6	300	10	Yes	8	Yes	48	65°	110°	E	G	90	E
7	350	14	No	8.5	Yes	44	70°	105°	E	G	82	G
8	300	8	No	7.5	-	63	80°	137°	G	E	100	E
9	250	7	No	7	Yes	24	65°	115°	E	E	92	E
10	200	11	No	5.5	-	52	85°	120°	E	E	94	E
11	300	9	No	7	-	49	70°	105°	E	G	90	E
12	350	9	No	8	Yes	40	65°	100°	E	G	84	G
13	200	12	Yes	6.5	-	65	85°	140°	E	E	100	E
14	600	10	Yes	7.5	Yes	45	70°	115°	E	E	92	E
15	400	7	Yes	7	-	62	55°	100°	E	G	90	E
16	250	8	Yes	6.5	-	38	50°	115°	E	E	84	G
17	300	10	Yes	6	-	47	75°	130°	E	E	94	E
18	400	12	No	5.5	-	45	80°	120°	E	E	97	E
19	500	11	No	8.5	Yes	69	50°	90°	E	G	76	G
20	400	12	Yes	7	-	42	65°	105°	E	G	84	G
21	450	8	No	5.5	-	38	70°	110°	E	G	90	E
22	200	7	No	8	-	29	55°	95°	E	G	84	G

EFP (External Fixation Period), mons (months), ROM (Range of motion), E (Excellent), G (Good), F (Fair).

and closed DFF [2,5,6,9,22,23,25]. Exclusive open DFF case series are few [1,3,4,14,21,24]. Similarly, some studies reporting Ilizarov fixator included both open and closed fractures [25,26], or both DFF and nonunions [11,12]. Open DFF studies presented variable treatment methods viz. both internal and external fixation [1], staged internal fixation [21], acute internal fixation [24], and external fixation (Taylor spatial frame "TSF" [4], hybrid external fixator [8], Ilizarov fixator [3,14]).

In the current study, all fractures successfully united without significant shortening or malalignment. Ilizarov fixator versatility allowed fine-tuning of any residual postoperative deformity. Comminution could make anatomic reduction of all fragments impossible. Therefore, restoration of alignment should be achieved regardless of the fracture complexity [27]. Rates of union, shortening, malalignment, and infection varied in different studies. Iyengar et al. [1] reported 14 malalignments and 11 cases of shortening (2–7 cm) in 18 open 33C3 fractures treated by variable fixation methods including five by Ilizarov fixator. Sala et al. [4] reported three nonunions and four abnormal mechanical axis deviations in 20 open DFF treated by TSF.

Two cases of the present study had deep infection, but none had septic arthritis. Hutson and Zych [26] reported one septic knee in 16 fractures treated by circular fixator. Antibiotic cement was not used in the present study in contrast to some other studies [5,21,23]. However, this is supported by the findings of Ricci et al. [24] who reported no difference in infection rate between a more aggressive debridement with antibiotic cement spacers, and a less aggressive protocol with debridement of grossly contaminated bone without antibiotic cement.

EFP in the present series averaged 7.05 months (30.65 weeks). EFP was different among studies (19 [3], 45 [4], 30 [8], 39 [14], 25 [26] weeks). Ali and Saleh [10] reported EFP of 6.8 months for open fractures group, and 5.2 months with closed fractures.

Most patients of the current study achieved flexion ROM of 100° or more. Only two cases had flexion ROM of less than 90°. Limitation of knee ROM is a common complication following DFF [1,5,6,22]. K-wires and pins were criticized for soft-tissue tethering and impending joint motion [11]. McElvany et al. [28] recommend pin insertion at more than 0.7 cm proximal to the adductor tubercle for avoiding intra-capsular penetration. However, this was not

feasible in the current series for comminution. To improve ROM, every effort was made for articular reconstruction. The anteriorly inserted pins helped correction of the recurvatum. Otherwise, if the reconstructed condyles were fixed to the ring in recurvatum relative to the surrounding soft-tissues, deformity correction could be too difficult, and much force could apply much stresses on the wires. Also, the knee was flexed to stretch the quadriceps when the wire or pin passes through it to minimize its checkrein effect to flexion. Moreover, percutaneous release of the ilio-tibial band and capsule around the pins and wires was done.

Long-term trans-articular immobilization leads to knee stiffness, cartilage destruction and muscle fibrosis [1]. In the current study, across-knee frame was done in 8 cases for severe comminution (six cases including concomitant extensor mechanism injury with one patellar tendon and three quadriceps muscle injuries), one non-displaced fracture patella, and one tibial plateau. The aim was unloading of the comminuted articular surface and/or protecting the associated injuries. It was removed after 4–5 weeks under anaesthesia to permit gentle knee manipulation. The tibial plateau frame was kept till its healing while the connections between tibial and femoral frames were removed.

The significantly lower post-removal ROM compared to final ROM could be attributed to the initial residual effect of mechanical limitation by the frame and soft-tissue tether with the long fixation period. However, the final improvement highlights the importance of physiotherapy and quadriceps-plasty when indicated. Normal gait requires 67° flexion during the swing phase, 93° to rise from a chair, 83° for stair climbing, and 90° for descending stairs [29]. The mean range of knee flexion of the present study was 107.59°. This was less than the results of Rademakers et al. [9] (118°), and Agrawal and Kiyawat [22] (121°), but comparable to some reports (106° [5], 109° [6], 110° [14]). However, it was better than other reports (49° [1], 77° [3], 95° [4], 88° [21], 87.5° [8]). Using Ilizarov fixator for 20 open DFF, Kumar et al. [14] achieved mean ROM of 110° in type C2, and 73° in C3 fractures, but with extension deficit of 5°–10°.

Two cases of the present series had radiographic osteoarthritic changes. Agrawal and Kiyawat [22] reported that in 3 of 16 C3 DFF. However, long-term studies are needed to estimate the true incidence of posttraumatic osteoarthritis. Rademakers et al. [9]

reported moderate to severe osteoarthritis in 36% of 67 intraarticular DFF treated by ORIF after a mean of 14 years.

The mean Neer score of the current study was 86.6 with 21 cases of excellent to good results. Rademakers et al. [9] reported good to excellent results in 84% of cases with Neer score (Mean 84; Range 48–100). Sala et al. [4] reported a lower mean score of 78.8 with good to excellent scores in 89%. They found TSF less technically demanding than traditional Ilizarov fixator. However, its remarkably higher costs could be a limiting factor in decision making [30].

The current study presents mid-term results of a prospective study of the challenging open comminuted DFF treated by an approach that could improve the outcome with careful articular reduction, simple recurvatum correction, proper wire/pin insertion with tether release, early weight-bearing, fine-tuning of alignment, intensive physiotherapy, and release of adhesions when needed. However, it has several weaknesses. The small series could be explained by the rarity of the selected fractures, in addition to the strict inclusion criteria to have a homogeneous group of fractures. Other limitations include the lack of a control group, and lack of long-term results for better evaluation of osteoarthritis development.

Conclusions

Ilizarov fixator provided a viable treatment option for open comminuted DFF with a high union rate in adequate alignment and satisfactory functional outcomes. However, the reduced knee motion remains a challenging complication. The presented approach could be a way to improve the outcomes.

Conflict of interest

The authors declare that they have no conflict of interest.

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