Ilizarov external fixator in the treatment of nonunion of the distal femur

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ABSTRACT

Background:
Nonunions of the distal femur fracture is an uncommon yet challenging complication. The current study aimed at presenting the radiographic and clinical outcomes after using the Ilizarov external fixation in the treatment of these nonunions.

Methods:
The current retrospective case series included 12 male patients with a mean age of 41.67 years with distal femur nonunion treated by Ilizarov fixator. The original fracture type was 33A2 (two cases), 33A3 (four cases) and 33C2 (six cases) based on AO/OTA system. Nine cases (75%) were infected and three (25%) were aseptic. The duration from the initial trauma till Ilizarov fixation averaged 15.42 months. Six cases had associated angular deformity. Assessment of the bone results and the functional results was performed according to the ASAMI criteria.

Results:
Time in the fixator averaged 163.75 days (Range 135- 190). The mean follow-up duration was 35.33 months (range, 24-48 months). All patients achieved complete union without major complications or deep infection. One case healed with a 7° valgus angulation. Two cases had residual shortening of 2.5 cm and 3 cm respectively. At the last follow-up, the knee range of motion averaged 72.5 degrees. The ASAMI bone result was good in these three cases (25%) and excellent in nine cases (75%). The ASAMI functional result was excellent in only two patients (16.7%), good in eight patients (66.7%), and fair in two (16.7%)

Conclusions:
The Ilizarov external fixation technique can be used as an effective treatment option with low complications in the management of nonunited distal femoral fractures that may be difficult to manage using other means of fixation.

Keywords:
Distal femoral fracture; nonunion; Ilizarov; external fixation
INTRODUCTION

Femoral supracondylar fractures account for 4 to 7% of all fractures of the femur [1]. It shows bimodal age incidence being more common in females over 50 years old following low-energy trauma, and in younger patients due to sports injuries and road traffic accidents [1-3]. These fractures are often difficult to treat, and need special management with many treatment options including internal fixation by antegrade or retrograde intramedullary nails (IMN) or by different plates (condylar, dynamic condylar, and locked) [4,5]. The success of internal fixation is determined by stability of fixation and the amount and quality of the bone stock. However, there is no agreement on a fixed treatment option among orthopedic surgeons [3,6].

Distal femoral non-unions are rare because the distal femur has an abundant blood supply and good intrinsic healing capacity but when they occur, union is difficult to obtain [7]. Fractures of the distal femur in patients with osteoporotic or osteopenic bone are challenging because of inadequate fixation strength and high failure rates [8-11]. A poor bone stock, short distal fragment, pull of the gastrocnemius muscle, and the proximity to the knee joint are factors leading to non-unions in distal femoral fractures [7]. High-energy open fractures with associated significant comminution and failed internal fixation are other causes of nonunion.

Distal femur nonunion is a challenging problem for which there are no current standard guidelines of treatment despite the reports of different treatment modalities [12]. Treatment options of distal femoral nonunions include bone grafting, revision of internal fixation by locked plates, revision IMN, nail pate combination construct, unilateral and circular external fixators, and primary total knee arthroplasty [13-15]. In cases of recalcitrant distal femur nonunions, especially in elderly, the risks of failure of another fixation are high because of osteoporosis and inadequate bone stock. In these cases, arthroplasty provides a good option [15]. In revision cases, arthrodesis or even above-knee amputation may be considered as a salvage procedure [16,17].

This study was designed to evaluate the mid-term radiographic and clinical results of treating nonunions of the distal femur fractures using the Ilizarov external fixator.

PATIENTS AND METHODS

Between January 2014 and December 2016, 12 patients presenting with a distal femoral fracture nonunion were considered for treatment with Ilizarov circular external fixation. The inclusion criteria were (1) infected nonunions of distal femoral fractures, (2) aseptic non-unions with a weak bone stock of the distal segment that is inadequate for good purchase of internal fixation, and (3) a minimum follow-up of two years. The exclusion criteria included acute fractures, nonunions treated by bone grafting with or without revision internal fixation, and patients who did not complete at least two years of follow-up. The clinical findings, surgical records, radiographic and CT scans findings, and functional results were retrospectively reviewed.

All patients of the series were males with a mean age of 41.67 years (Range 22-62; SD 14.82). The mechanisms of initial injury were motor vehicle accidents in seven cases (58.3%), gunshot injury in two cases (16.7%), and fall from a height in three cases (25%). Seven fractures (58.3%) were in the right side, and the left side was affected in the remaining five (41.7%). Two patients were diabetics and five were smokers. Distal femoral fractures were classified as 33A2 (n=2; 16.7%), 33A3 (n=4; 33.3%) and 33C2 (n=6; 50%) according to the AO/OTA system [18]. Concomitant injuries occurred in five patients.
including an ipsilateral patellar fracture, an ipsilateral tibial fracture, an ipsilateral talus fracture, a contralateral acetabular fracture, and a contralateral Colles’ fracture.

The initial treatment of the fracture consisted of open reduction and internal fixation (ORIF) (n=7; 58.3%), retrograde nail (n=2; 16.7%) and monolateral external fixator (n=3; 25%). Six nonunions were atrophic, four were oligotropic, and two were hypertrophic. Nine cases (75%) were septic and three (25%) were aseptic. The time interval from the initial trauma till the application of Ilizarov fixator averaged 15.42 (Range 10-24; SD 4.69) months. Four cases had a varus deformity, and two had a valgus deformity. All patients had more than one previous surgery including the primary fixation in addition to bone grafting, implant removal, and debridement with a mean of 2.75 (Range 2-4; SD .75) procedures (Table 1).

Table 1. Patient demographics

<table>
<thead>
<tr>
<th>Case</th>
<th>Side</th>
<th>Age</th>
<th>Mechanism of initial injury</th>
<th>Initial treatment</th>
<th>Nonunion duration</th>
<th>Number of previous surgeries</th>
<th>Type of nonunion</th>
<th>Sepsis</th>
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<tr>
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</table>

* Lt (Left), Rt (Right), DFLP (Distal femoral locked plate), Unilat Ex Fx (Unilateral external fixator), IMN (Intramedullary Nail)

Operative technique:

The patient was placed in a supine position under general or regional (spinal or epidural) anesthesia on a radiolucent table. In infected cases, the procedure started by adequate debridement of the nonunion site with removal of any internal fixation implants. All fibrous and necrotic soft and bone tissues were adequately debrided till the appearance of the cortical bleeding. With aseptic cases, a closed technique was used with refreshing the nonunion site by percutaneous drilling. One ring was applied to the distal femur segment and fixed by at least four wires including olive wires. After reference wire insertion, two wires were directed from posteromedial to anterolateral and from posterolateral to anteromedial respectively. A drop wire was inserted for more stability at an extra-level. Adding a more
distal ring across the knee attached to the proximal tibia was done in cases of small osteopenic distal femoral fragment. Proximally, the femoral shaft was fixed by one ring and an arch anchored to the femur by Schanz pins. The wires and Schanz pins were inserted through the safe zones described by the goniometric atlas of ASAMI [19].

Thereafter and under image intensifier guidance, a reduction of the supracondylar nonunion was performed with connecting the distal femoral ring to the proximal femoral construct by four threaded rods. Finally, the frame stability was checked and crepe bandages were applied over dressings on the wounds of debridement. Any residual element of deformity was corrected gradually postoperatively. In this series, no bone graft was used and no case necessitated radical resection or had a bone defect needing bone transport.

**Postoperative Care:**

All patients received parenteral antibiotics for two days. In septic non-unions, appropriate antibiotic therapy, according to the results of the culture and antibiotic sensitivity testing, was continued for six weeks. Patients were allowed to shower two weeks after surgery after removal of the sutures. The patients were instructed to perform regular pin site care. Postoperative weight bearing was allowed on the second postoperative day as tolerated with regular quadriceps isometric exercises. Repeated cycles of compression and distraction were used to stimulate healing. In cases with residual angulation, gradual corrections were made as appropriate.

Follow up of patients was done monthly for routine clinical and radiological assessment until removing the circular fixator, and every three months thereafter. The proximal tibial ring was removed after appearance of the early radiographic signs of healing. It was removed under general anaesthesia to permit subsequent gentle manipulation of the knee joint to improve its ROM. Postoperative radiographs were evaluated for any residual malalignment and progression of union. Union was defined radiographically as the absence of the radiolucent lines at the site of the fracture in at least three cortices on the standard anteroposterior and lateral radiographs (Fig. 1). Clinically, painless ambulation on a fully dynamized fixator without a walking aid was used as a clinical indicator for union. According to the ASAMI criteria, the bone result and the functional result were evaluated for all cases [20].

**Statistical Analysis:**

The descriptive analysis was done by means of the Version 22.0 of IBM SPSS Statistics, presenting the qualitative variables in frequencies and percentages, and the quantitative variables in means, ranges, and Standard Deviations (SD).

**Figure 1**

(a) Preoperative radiographs and CT scans (b) of an infected distal femur nonunion with previous plate removal with medial translation and varus angulation of the distal fragment. (c) Postoperative radiographs showing frame extension across the knee and mild residual varus deformity. (d) Radiographs after complete deformity correction and removal of the proximal tibial ring with progression of healing. (e) Radiographs after external fixator removal showing sound bony union.
RESULTS

The operative time averaged 99.58 (Range 75-135; SD 16.16) minutes. Extending fixation across the knee was done in seven cases, and removed after an average of 9.57 (Range 8-12; SD 1.51) weeks. No iatrogenic neurovascular injuries occurred. The mean follow-up period was 35.33 (Range 24-48; SD 8.48) months. The external fixation period (EFP) averaged 163.75 (Range 135-190; SD 15.83) days. Successful union was achieved in all 12 patients after one operation without additional procedures (Table 2). Superficial pin-tract infections occurred in eight cases and were treated with local wound care and oral antibiotics. Control of infection was achieved in all infected cases.

Table 2: Summary of the study outcomes

<table>
<thead>
<tr>
<th>Case</th>
<th>EFP (days)</th>
<th>Follow-up (months)</th>
<th>Flexion ROM (degrees)</th>
<th>Shortening (cm)</th>
<th>Bone result</th>
<th>Functional result</th>
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<tbody>
<tr>
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<td>39</td>
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<td>190</td>
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At the last follow-up visit, all 12 patients were capable of painless full weight bearing on the affected limb without any walking aid or brace (Fig. 2). Refracture did not occur in any case. Three patients had mild pain on exertion. None suffered from sympathetic dystrophy. Another three patients had obvious limp secondary to arthritis following a talar fracture in one case, and shortening of 2.5 cm and 3 cm respectively in two cases. Leg length discrepancy (LLD) of the last two cases was much improved by a shoe-lift. One case healed with a residual 7° valgus angulation. All patients returned to their daily normal activities and their original work as drivers (five), farmers (three), and employees (four). Therefore, the ASAMI bone result was good in these three cases (two LLD and one valgus angulation). The remaining nine cases (75%) had excellent bone results. On the other hand, the ASAMI functional result was excellent in only two patients (16.7%), good in eight patients (66.7%), and fair in the remaining two (16.7%) secondary to the significant limp and the reduced ROM. All patients had a full knee extension ROM. The range of knee flexion early after removal of the circular fixator averaged 39.17 (Range 15-70; SD 18.07) degrees. However following a supervised physiotherapy program, the mean flexion ROM was significantly improved at the last follow-up and became 72.5 (Range 30-100; SD 23.21) degrees.

**Figure 2**
Clinical photos showing the patient after removal of the Ilizarov fixator in a full weight bearing showing good alignment and range of knee motion

<table>
<thead>
<tr>
<th></th>
<th>160</th>
<th>48</th>
<th>75</th>
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*EFP (External fixation period), ROM (Range of motion)
DISCUSSION

Distal femur fractures have lower union rates and higher incidence of mechanical failure and overall re-operation rate than the femur shaft fractures [21]. The incidence of distal femur fractures nonunion is up to 6%. These nonunions are a disabling and necessitate complex steps in their treatment. Successful nonunion treatment relies on adequate mechanical stability while optimizing the biological environment [22, 23]. The treatment is challenging and difficult because of short distal fragment, poor soft tissue coverage, thin cortex and poor bone stock due to disuse atrophy and implant failure [4,11]. The presence of an associated infection in these nonunions makes the treatment even harder [10]. All these obstacles were seen in the current series.

Variable results have been reported after revision of internal fixation by either nails or plates with frequent complications such as persistence of non-union, knee stiffness, and malalignment [13,14,16, 24]. Primary arthroplasty has been suggested for the elderly patient, in order to increase the mobility and decrease time of bed rest or wheelchair [9,15].

Retrograde nailing has the advantages of minimal soft tissue trauma and it provides a load-sharing implant. However, its insufficiencies in deformity correction and in stable fixation at the distal fragment due to poor hold of the distal locking screws limit its use in non-unions with poor bone quality and restrict early weight bearing. Intramedullary nailing used for treatment of femoral non-unions, was reported to fail in 30% of patients using antegrade and 50% using retrograde techniques [13,14].
Distal femoral locking screw plate implants have been popularized because friction and compression forces of the plate on the surface of bone are not necessary to gain stability of the bone-implant construct, which results in lower rates of screw pull-out in osteoporotic bones [5]. In addition to the different success rates, the locking plates still require a long period of delayed full weight bearing as with any other internal fixation method [9,11]. Moreover, the need for bone grafting and the risks of deep infection are still associated problems [25]. Some studies reported union in all cases after revision of internal fixation [26-27]. The study of Gardner et al. [28] involved 31 distal femur nonunions treated by initial implant removal and fixation with angled blade plates, dynamic condylar screws, or locking compression plates in addition to either autogenous iliac crest bone graft or demineralized bone matrix. A union rate of 97% was achieved.

On the other hand, Ebraheim et al. [12] reported union in only eight of 14 distal femur nonunions (57%) after treatment by revision of internal fixation with a locking plate (11 cases) with additional medial plating (two cases), bone grafting and using other biologic materials (three cases). They reported a number of complications including two patients with iliac crest donor site complications, two wound infections, one knee arthrofibrosis, one post-traumatic arthritis, two cases of implant failure, and one valgus malunion.

The Ilizarov circular fixator is a good treatment option in the treatment of many complicated musculoskeletal problems including nonunions even in the presence of infection [8,10]. It has several advantages providing adequate fixation and stabilization that permits early weight bearing, thence reducing the serious medical complications secondary to immobilization. Moreover, the tensioned wires provide adequate purchase and stability even with osteoporotic bones. Also, it allows for correction of angulation and rotation at the nonunion site while providing multiplanar stability [1,29]. However it has been associated with many complications such as joint stiffness, pin-tract infection, and bulky external frame necessitating care and compliance of the patients [30,31].

Whereas the reported studies of distal femur nonunions are few, the studies reporting the use of Ilizarov fixator are scarce and some are heterogeneous including other nonunion sites in the same study [32,33] or using Ilizarov fixator in some cases and monolateral fixator in others [8]. The current study evaluated a homogenous group of 12 patients with nonunited supracondylar femoral fractures treated with the Ilizarov fixator. Most cases of the series (n = 9; 75%) were infected nonunions. However regarding the non-infected cases, it is difficult to decide whether the nonunion is infected or aseptic with negative history and signs of infection. Kim et al. [34] found that 13.6% of 22 presumptive aseptic distal femur nonunions had positive results culture in intraoperative samples and this incidence reached 20% in those complicating an initial open fracture.

Sound healing was achieved in all cases with the stable frame, early progressive weight bearing, and repeated periods of compression and re-distraction. Additionally, the versatility of the circular fixator allowed postoperative deformity adjustment. In this series, despite the common finding of superficial pin-tract infections there was no deep infection and there was infection control in all infected cases. Similarly, in the study by Cavusoglu et al. [35], superficial pin-tract infection was reported in all cases but none developed deep infection.

The present study shows the outcomes of one stage treatment approach. A three-stage treatment protocol was used by Ma et al. [22] to treat 12 distal femur nonunions after exclusion of infected cases. They started by debridement and length restoration using a monolateral external fixation, followed by deformity correction with stabilization by a locked plate and filling the defect with a cement spacer. Lastly, the bone defect was reconstructed.
by either the Masquelet technique or vascularized fibular grafting. Union was successful in all cases with excellent to good results in nine patients with the HSS scoring system.

Ali and Saleh [36] reported treatment of 15 distal femur nonunions including five infected cases by external fixation. Union was achieved in 14 of 15 cases without any deep infection. Saridis et al. [10] reported treatment of 13 infected cases by Ilizarov fixator with bony union and infection control in all patients. The bone results were excellent to good in 12 patients and fair in the remaining one. The functional results were excellent and good in seven patients, fair in four cases and poor in the remaining two. The ROM was full in three patients and less than 90° in the remaining ten including five cases with restriction to 0° to 10°.

With associated preoperative knee stiffness in these nonunions, the lever arm is lengthened resulting in high stresses at site of nonunion site and possible loosening the distal fixation [36]. To avoid this and to stabilize a small distal fragment in the current series, the fixation was extended across the knee in seven cases of the present study. The final mean knee ROM in the present study was 72.5 degrees. Despite this ROM restriction in these cases, a satisfactory outcome was obtained. To reduce the soft tissue tethering effect of the wires and pins, the knee was flexed while the wires or pins passing through the quadriceps muscle. In addition, soft tissue release was done at the pin sites. ROM was significantly improved with follow up. This could be attributed to early weight bearing and ROM with the intensive physiotherapy program. The reduced knee ROM is a common finding after treatment of acute distal femur fractures [37]. However, in case of nonunited distal femoral fractures, the ROM is more restricted due to prolonged immobilization and repeated previous surgical interventions. Reports of knee ROM varied among studies of distal femur nonunions including 60° [32], 80° [36], 90.4° [22]. Other studies did not present their average ROM [8,12,38].

While the current study reports treatment of a homogenous group of distal femur nonunions with satisfactory outcomes, it has its obvious limitations including the retrospective approach and lacking of a control group. Moreover, the small number of cases involved in the study limited the ability to do any analytic testing with a statistical significance. However, this is attributed to the known uncommon incidence of this nonunion. Several reported studies of distal femur nonunions included a series of 12 to 15 patients [12,15,22,27,36,39]. Future multi-center prospective large-series studies would provide better assessment of these difficult nonunions and their different treatment modalities.

Conclusion

The use of Ilizarov circular fixator provided an effective treatment option in the difficult cases of distal femur nonunions with the small distal fragment. It achieved satisfactory outcomes even in the presence of infection. However, the commonly reported complication of reduced knee range of motion was noted in all cases.

References


4. **Hailer YD, Hoffmann R.** Management of a nonunion of the distal femur in osteoporotic bone with the internal fixation system LISS (less invasive stabilization system). *Arch Orthop Trauma Surg* 2006; 126: 350-353.


