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Periarticular large bone defects treatment with ring external fixator

Thanase Ariyawatkul, Kamolporn Kaewpornsawan, Perajit Eamsobhana*

Department of Orthopaedic Surgery, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand

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ABSTRACT

Background: Joint stiffness and limited bone stock for fixation were the main problems in management of periarticular bone defects. The present study aimed to report clinical and radiographic outcome of periarticular, large (≥8 cm) bone defects treated with ring external fixator.
Materials and methods: Seventeen patients (10 males and 7 females) who had periarticular bone loss at the minimum of 8 cm were treated with ring external fixator. Acute shortening and subsequent lengthening at the corticotomy site were performed in 5 patients. Bone transport was performed in 12 patients. Clinical outcome and radiographic outcome were reviewed.
Results: Seventeen patients (10 males and 7 females). Mean age was 31.1 years (9–52 years). Mean bone gap was 9.17 cm (8–14 cm.). Mean follow-up period was 39.7 months (30–60 months). Fracture united primarily in 14 cases and after iliac bone graft in 2 cases. One patient had nonunion. Based on ASAMI evaluation;The bone result was excellent, good, and poor in 13, 3, and 1 patients, respectively. The functional results were excellent and good in 14 and 3 patients respectively. Ten patients had superficial pin tract infection.
Conclusion: Periarticular large bone defects were successfully treated with ring external fixator by bone transport or acute shortening and subsequent lengthening at corticotomy site. Superficial pin tract infection and joint stiffness were common problems in management of periarticular large bone defects. Early convert to internal fixation after achieve the acceptable length or after successfully bony contact of bone transport fragment to allowed early motion of the joint was recommend. Good to excellent functional outcomes were achieve in majority of the patients.

1. Introduction

Periarticular large bone defect resulting from of high-energy trauma or following surgical debridement was a very difficult problem in orthopedics practice. Problems of management in this area included limited of bone stock for fixation, sequelae of joint stiffness, infection, deformity, shortening and loss of soft tissue coverage. Management modalities in literatures such as Papineau type cancellous bone grafting, cancellous allograft in fibrin sealant mixed with antibiotics and /or free microvascular soft tissue and bone transplants, etc. had been described to treat bone loss.[1–6] Fractures with ≥ 8 cm. bone defect required individualized treatment. Vascularized fibular grafts have been used successfully to treat large bone defects but this procedure required technical expertise in microvascular surgery and it was a time consuming procedure. The distraction osteogenesis has been successfully used to treat large bone defect for many years. Bone transport could be done through many devices like ring fixators, monolateral fixators or intramedullary nail system. Few studies in literature have focused on outcome of ring fixator in periarticular large bone defects treated with distraction osteogenesis.[6–8] The present study aimed to evaluate radiologic and functional outcome of ring fixators in large (≥8 cm) periarticular bone defects treated with ring external fixator.

2. Materials and methods

The present study included patients of posttraumatic, infected at periarticular around the knees and ankles who have bone loss > 8 cm. treated with ring external fixator between 2000 and 2012. The study was approved by institutional review board. The patients excluded from study were pathological fractures, any medical or skeletal illness affecting bone healing and patients with less than 12 months of follow-up. Seventeen patients were included in this study. There were 10 males and 7 females with the mean age of 31.1(10–52) years. Details of initial injury,

* Corresponding author at: Department of Orthopaedic Surgery, Faculty of Medicine Siriraj Hospital, Mahidol University, 2 Wanglang Road, Bangkoknoi, Bangkok 10700, Thailand.
E-mail addresses: Thanase@gmail.com (T. Ariyawatkul), sikkw@mahidol.ac.th (K. Kaewpornsawan), perajit@mahidol.ac.th (P. Eamsobhana).

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previous treatments, initial shortening, deformity, neurovascular deficiency, and condition of soft tissue were documented. Patients and family education about the operative procedures, postoperative care, approximate duration of treatment and the associated complications of reconstructive surgery were informed to all patients and families. Informed consent was complete in all patients. Right side was involved in 10 patients and left side was involved in 7 patients. The bone defect mainly involved distal of tibia in 7 patients, distal femur in 9 patients and proximal tibia in one patient. 15 patients had open fractures at the time of original injury and 2 patients has osteomyelitis with subsequence bone loss after sequestrectomy. The mode of trauma was road traffic accidents. The previous treatment was spanning external fixation in 14 patients, and locking compression plate in

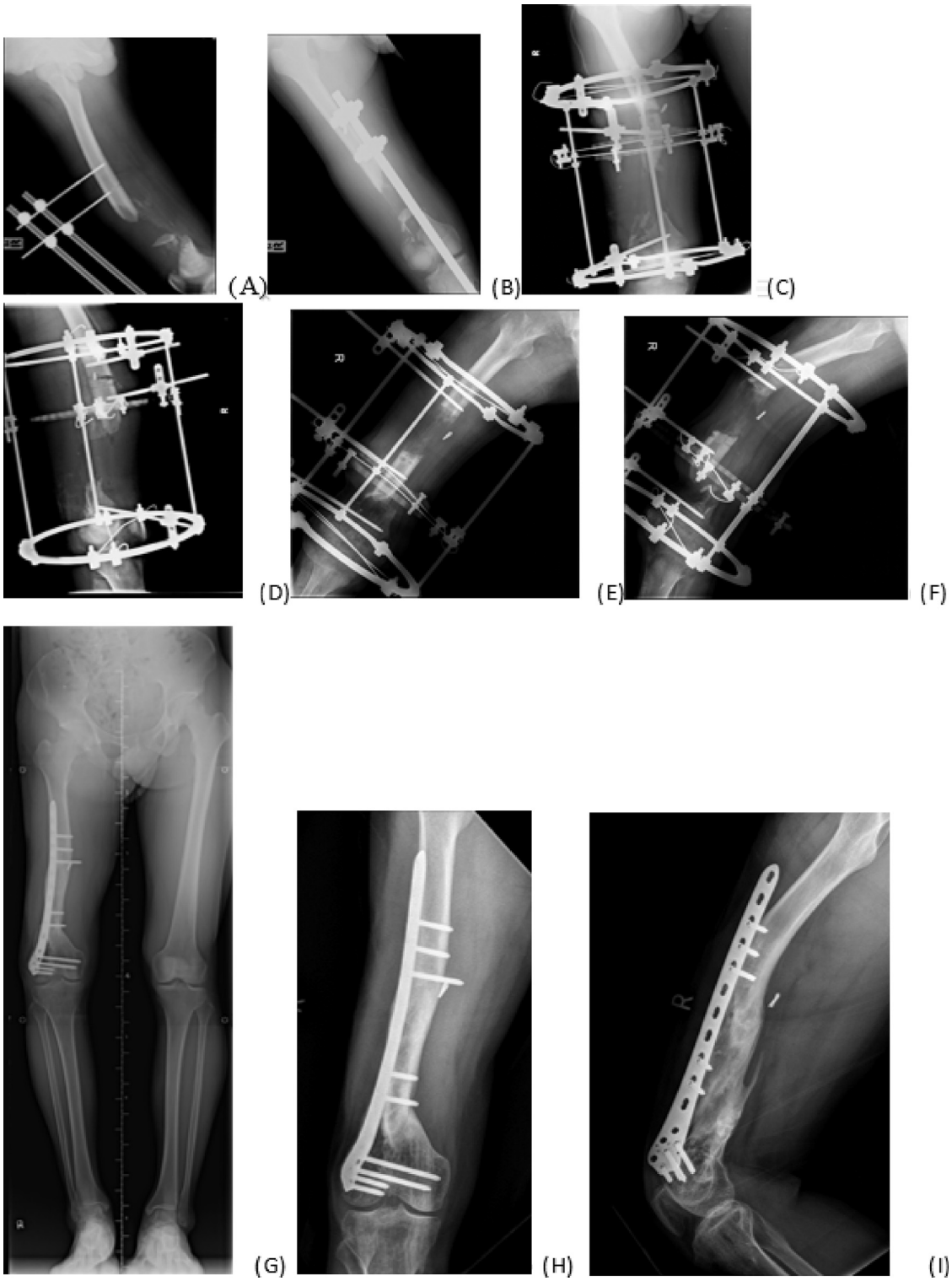

Fig. 1. A, B; 17 year -old male suffered from road traffic accident and got bone loss 9 cm at the distal Rt. Femur. C–F; Ilizarov fixation and bone transport was performed. G–I; Conversion to locking plate and screws system with residual LLD 2 cm. Range motion of right knee; flexion to 120 degrees with full extension.

3 patients. Average number of operations performed before application of ring external fixator was 3.9. The mean time between injury and definitive frame application was 9.4 months (range, 2–30 months). Operative treatment included soft tissue debridement, removal of implant, exposure of fracture site, radical resection of necrotic, fibrous tissue. The sclerotic bone was cut in order to obtain healthy bleeding bone on both side of bony ends, and drilling of medullary canal. Bone transport was performed in patients who have good soft tissue coverage. The ring external fixator frame was applied and corticotomy was done at metaphysis area in the cases who had performed bone transport. In patients who have the problem of soft tissue coverage; acute shortening of the bone defect and subsequent lengthening through the corticotomy from proximal/distal metaphysis area were performed. The mean bone gap was 9.17 cm (range, 8–14 cm). The standard ring fixator frame included four rings, with three rods and on an average of 8 wires per patient. During wires insertion; the muscle and soft tissue were stretched at the time of transfixion to ensure maximum joint movement. The frame was applied according

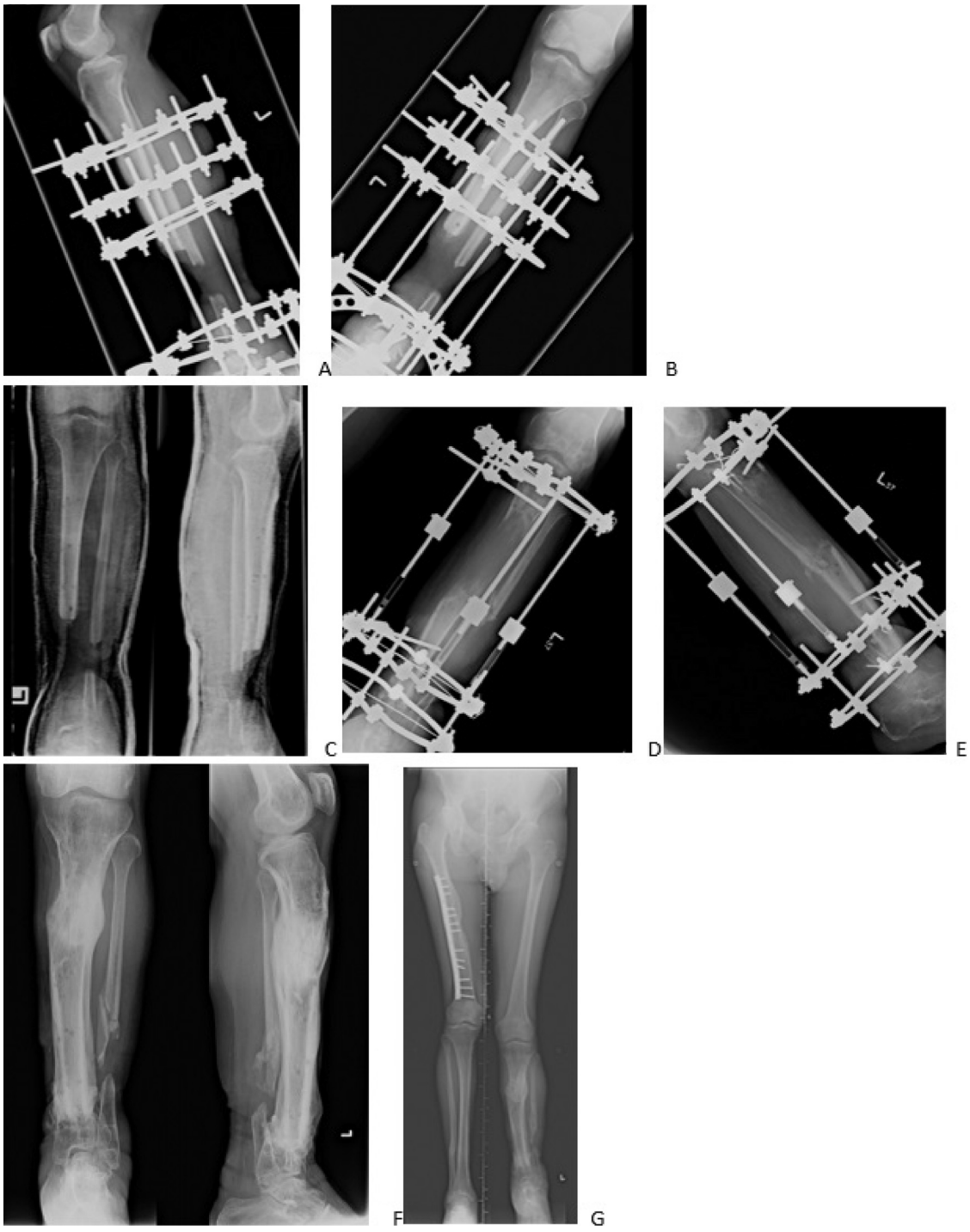

Fig. 2. A–C; 50 year old male suffered from road traffic accident and got 8 cm. bone loss at left distal tibia s/p circular frame external fixation. D, E; Bone transportation through ilizarov was performed. F, G; Tibial union was achieved with residual LLD 2.5 cm, ankle dorsiflexion is 15 degrees and plantar flexion is 10 degrees.

to the technical principles reported by Ilizarov.[18] All patients had corticotomy at one level. Five patients had acute compression at bone defect site with distraction osteosynthesis at corticotomy site. Twelve patients had bone transportation. The fibular osteotomy or resection was performed in acute shortening of the bone defect area. Closure of the wound was successfully in all patients. In the postoperative period, joint motion and partial weight bearing with crutches or walker were encouraged to patients. Distraction with the rate of 1 mm per day divided in four times /day was started at 1 week after ring external fixator application. Pin site care was taught to all patients before discharge. All patients were follow up in outpatient unit at 2 weeks after operation and then monthly for clinical and radiographic evaluation until frame removal. Assessment of complications included muscle and joint contractures, lengthening axis deviations, premature/delayed consolidation, refracture, and pin tract infections was done at each follow-up. Pin tract infections were classified according to Paley's classification into grade 1, grade 2, and grade 3.[17,19] Grade1 and grade 2 infections were labeled together as “superficial pin tract infections”. Grade 3 infections were labeled as “deep pin tract infections”. Superficial pin tract infection was treated by local wound care, incision/drainage, and oral antibiotics. Deep pin tract infection was treated by local wound care, incision/drainage, intravenous antibiotics, and pin removal if necessary. Rate of distraction was adjusted based on the radiographic appearance of the regenerate bone. If necessary, the frame was adjusted under anesthesia to correct malalignment; adjustment may include adjust alignment of lengthening corticotomy, excision of interposed soft tissue and add some wires. Bone grafting from iliac crest was done at nonunion site after excision of interposed soft tissue and created healthy bleeding bone in the patients who had no radiologic evidence of union after 3 times of consecutive follow up after successful lengthening/transport. The frames were retained until

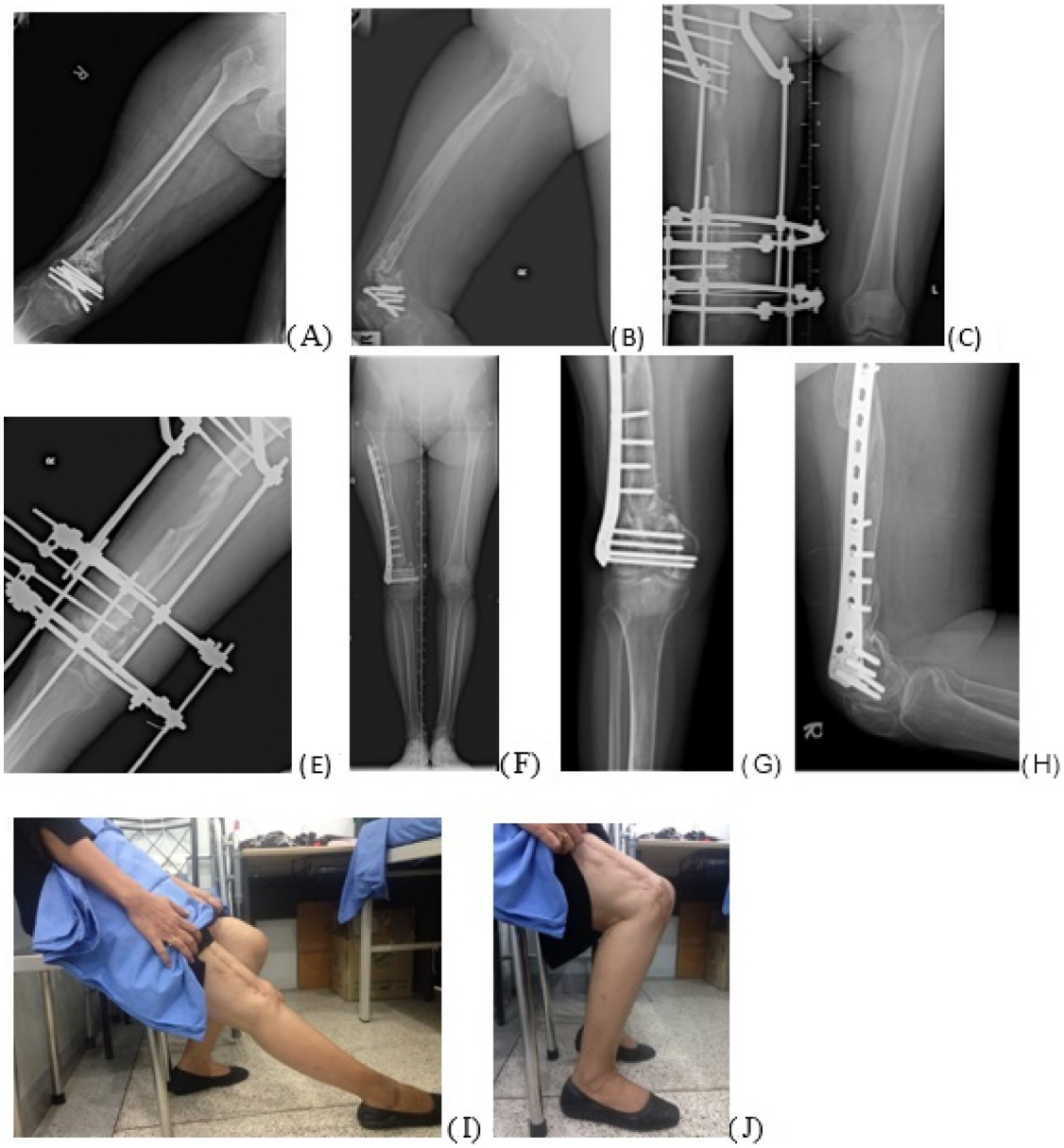

Fig. 3. A, B; 51 year old female suffered from road traffic accident s/p internal fixation with subsequence loss of fixation and osteomyelitis. C–E; Acute compression with subsequent lengthening at corticotomy site was performed. F–H; Conversion to internal fixation after achieved equal length. I, J; Range of motion; flexion 70 degrees with full extension.(Video motion) in supplement file.

adequate consolidation of the regenerate and fracture union was achieved or after converted to internal fixation. The frames were dynamized before removal. Result of treatment were assessed as bone results and functional results according to the classification of the Association for the Study and Application of the Method of Ilizarov (ASAMI).[14,15] The bone results were evaluated according to four criteria: union, infection, residual deformity, and limb length discrepancy. Union of the fracture was considered when it had bridging trabeculae at three of four cortices on anteroposterior and lateral radiographs, no motion at the fracture site after loosening of the frame and patient was able to walk without pain at fracture site. An excellent bone result was defined as union, no infection, deformity of < 7 degrees, and limb length discrepancy of < 2.5 cm; a good result, as union and any two of the other criteria; a fair result, as union and one of the other criteria, and a poor result, as nonunion or refracture or as union but none of the remaining three criteria.

Functional results were based on five criteria:

1 A noteworthy limp
2 Stiffness of either the knee (loss of $\geq$ 15degrees of knee extension) or the ankle (loss of $\geq$ 15 degrees of ankle dorsiflexion) compare to normal contralateral side
3 Soft tissue sympathetic dystrophy
4 Pain that reduced activity or disturbed sleep
5 Inactivity

The functional results were considered excellent if the patient was active and none of the other four criteria were applicable; good if the patient was active but one or two of the other criteria were applicable; fair if the patient was active but three or four of the other criteria were applicable; and poor if the patient was inactive. Amputation was considered as failure. Lengthening index was calculated by dividing the total time in external fixator (months) by the length of the regenerated bone in centimeters.

3. Results

There were no intraoperative complications. Mean follow-up period was 39.7 months (range, 30–60 months). Fracture united primarily in 14 cases (Figs. 1A–I, 2A–G, and 3A–J) and after iliac bone graft in 2 cases. One patient had nonunion at final follow-up. She walked partially weight with crutch and refused further treatment. All corticotomy sites healed. Mean gain in bone length was 8.9 cm (range, 8–14 cm).Two patients had limb length discrepancy > 2.5 cm. Six patients had residual deformity > 7degrees. No patient had persistent infection at fracture site. No patient had loss of > 15 degrees knee extension. No patient had loss of more than 15 degrees ankle dorsiflexion at final follow-up. Superficial pin tract infection occurred in 10 patients. No deep pin tract infection. Correction of deviation of transporting fragment was required in 8 patients by converted to plate and screws fixation and simultaneous corrected alignment at the same operation (Fig. 1G–I). No patient had refracture. The bone result was excellent in 13 patients, good in 3 patients, and poor in one patient. The functional results were excellent in 14 patients, good in 3 patients. (Tables 1 and 2) Mean lengthening index 1.59. Additional procedures included adjustment of the frame in 10 patients, insertion of additional wires in 8 patients, iliac bone graft in 3 patients, convert to internal fixation in 8 patients.

Table 1
Demographic data of the 17 patients.

No.	Age (yr.)	sex	side	area	Time to presentation (months)	Bone loss (cm.)	Length of bone distraction (cm.)	LLD (cm.) last follow up	Time to union (months)	Lengthening index	Follow up (months)
1	42	M	Lt.	Distal tibia	2	8	9	1.5	14	1.55	36
2	50	M	Lt.	Distal tibia	5	8	9	2.5	14	1.55	40
3	16	M	Rt.	Distal femur	2	9	10	2	8	0.8	36
4	51	F	Rt.	Distal femur	12	10	8	1.5	18	2.25	30
5	52	F	Rt.	Distal femur	4	8	8	3	Non union	2.1	30
6	18	M	Rt.	Distal femur	6	13	12	1	17	1.4	45
7	18	M	Rt.	Distal tibia	3	8	8	0	8	1	36
8	13	F	Rt.	Distal tibia	4	8	8	0	10	1.25	50
9	48	F	Rt.	Distal femur	8	9	8	1.5	14	1.75	35
10	23	F	Lt.	Distal femur	24	10	8	3	16	2	48
11	9	M	Rt.	Distal femur	30	14	14	2	24	1.7	30
12	10	M	Lt.	Distal tibia	24	9	8	0	10	1.25	60
13	30	F	Lt.	Distal tibia	10	8	8	1	10	1.25	40
14	48	M	Rt.	Distal femur	14	9	8	1.5	16	2	45
15	49	F	Lt.	Proximal tibia	2	8	8	2	15	1.87	40
16	24	M	Lt.	Distal tibia	4	8	9	1	16	1.77	36
17	28	M	Rt.	Distal femur	6	9	9	1.5	15	1.66	39

Table 2
Clinical data of the 17 patients.

No	Type of surgery	area	Knee flexion (degrees)	Knee extension (degrees)	Ankle dorsi flexion (degrees)	Ankle plantar flexion (degrees)	ASAMI bone result	ASAMI functional result
1	Acute shortening and lengthening at corticotomy site	Distal tibia			15	10	excellent	excellent
2	Bone transport	Distal tibia			15	10	good	excellent
3	Bone transport	Distal femur	120	0			excellent	excellent
4	Bone transport	Distal femur	70	0			excellent	excellent
5	Acute shortening and lengthening at corticotomy	Distal femur	40	0			poor	good
6	Acute shortening and lengthening at corticotomy site	Distal femur	60	0			excellent	good
7	Bone transport	Distal tibia			15	10	excellent	excellent
8	Bone transport	Distal tibia			15	15	excellent	excellent
9	Bone transport	Distal femur	90	0			excellent	excellent
10	Acute shortening and lengthening at corticotomy site	Distal femur	110	0			good	excellent
11	Bone transport	Distal femur	60	0			good	good
12	Bone transport	Distal tibia			20	15	excellent	excellent
13	Bone transport	Distal tibia			20	15	excellent	excellent
14	Bone transport	Distal femur	80	0			excellent	excellent
15	Acute shortening and lengthening At corticotomy site	Proximal tibia	60	0			excellent	excellent
16	Bone transport	Distal tibia			15	10	excellent	excellent
17	Bone transport	Distal femur	60	0			excellent	excellent

ASAMI; Association for the Study and Application of the Method of Ilizarov.

4. Discussion

Periarticular large bone defect was a group of difficult problems include significant loss of limb function, loss of motion of adjacent joints, disuse osteopenia, and some patients had persistent infection.[2,9,12] Multiple operations were needed in order to eradicate the infection, management of bone defect, management of sequelae after successful bone union such as residual leg length discrepancy, deformity, and joint contracture. Bony reconstruction procedures included open cancellous bone grafting, anterior cancellous bone graft beneath a flap, vascularized or nonvascularized transfer, nonvascular autogenous cortical bone grafts, transplant of allograft bone, and distraction osteogenesis have been reported for treatment of bone defect in many literatures.[1–3] However, options for periarticular bony defects $>$ 8 cm or more are limited. The present study reported outcome of ring external fixator in periarticular, large ($\geq$8 cm) bone defects treated with distraction osteogenesis. Goal of treatment was to obtain solid bony union, eradication of infection, obtain good alignment, equal limb length and gain maximum functional of the extremity.[1] Union was achieved primarily in 14 patients in the present study. Two patient (11.7%) required iliac bone grafting in the present study. Chaddha et al. reported bone grafting in 36% patients, Mahaluxmivala et al. reported that additional bone grafting was required in 83.3% patients in the bone transport group as compared to 16.7% in the acute shortening group.[15,22] More procedures were necessary in the bone transport group mainly to correct alignment.[17] This study has 8 patients with bone transport group required correction of deviation of transporting fragment by converted to internal fixation and simultaneous corrected alignment at the same operation (Fig. 1E–I). Soft tissue loss often added more complicates of the treatment that may require skin grafts, local pedicled muscle and myocutaneous flaps, and free flaps. Some patients required a microvascular team causing increase hospitalization time, cost, and morbidity.[7] Sen et al. reported patients with a soft-tissue defect, acute or gradual compression at the bony defect allowed primary or delayed primary closure without any secondary reconstructive procedure.[5] El-rosasy also reported acute limb shortening and appropriate skin incisions to close the defect.[21] We used technique of acute shortening and subsequent lengthening from proximal/distal corticotomy in 5 patients and had successful closed of soft tissue defect without the need for a flap. El-rosasy and Sen et al. reported pin tract infection in 23.8–30% patients.[5,21] Chaddha et al. reported pin tract infections in 80% patients treated with ring fixator.[15] Wani et al. also found pin tract infection as the most common complication associated with Ilizarov ring fixator.[13] Our study found superficial pin tract infection in 10 patients (58.8%). Pin tract problems were related to motion between pin/skin interface, amount of soft tissue between skin and bone, and the diameter of the pin.[11] Good care of pin sites and aggressive management of superficial infections was essential to prevent deep infections.[10,11,16] No ankle stiffness (dorsiflexion/plantar flexion $<$ 10 degrees) was observed in the present study. Significant joint stiffness has been reported in up to 56–63% patients operated with ring fixation system in literature.[6,8] Megas et al. also observed stiffness of ankle joint in 55% patients and reported it as a common and severe residual problem after such surgical intervention.[20] Transfixing of Kirschner wires through the muscle is one of the reason leading

to difficulty in physiotherapy causing joint stiffness.[4,11] Another reason is limited bone stock for fixation in periarticular area and needed to fixation across the joint for stable fixation leading to joint stiffness. Our study has knee motion range from flexion 60 degrees to 120 degrees. One patients has nonunion and knee flexion 40 degrees. We did not encourage this patients to do aggressive range of motion exercise due to this could create abnormal movement at the nonunion site instead of knee joint. Early conversion to internal fixation in patients with periarticular bone loss allows patients to do range motion exercise and less joint stiffness. The overall complication rate in present study was 1.7 complications per patient as compared to 2.8 reported by Chadda et al. and 1.59 by Paley.[15,17,19] The Ilizarov method was a comprehensive approach to all aspects of bone defect that simultaneously addresses deformity, shortening, infection, weight bearing, osteoporosis, and soft tissue atrophy.[9,10] The main disadvantage of ring external fixator is the long duration of treatment with marked patient discomfort. To overcome patient discomfort, Emara and Allam advocated early removal of external fixator and replacement by internal fixation.[23] In this study we converted to internal fixation with plates and screws in 8 of 17 patients mainly to correct malalignment and allow early joint motion to prevent stiffness. Limb reconstruction in the patients with periarticular bone loss usually involves surgery which was technically difficult and time consuming. The understanding in long process of treatment and cooperation of patients and families were very important in this complicated situation.[1,16]

Limitation of this study was limited by its retrospective nature and single center experience. Retrospective studies were subject to selection and indication biases.

5. Conclusion

Ring fixator systems were reliable method to achieve union in patients with periarticular large bone defects. Periarticular large bone defects were successfully treated with ring external fixator by bone transport or acute shortening and subsequent lengthening at corticotomy site Superficial pin tract infection and joint stiffness were common problems in management of periarticular large bone defects. Conversion to internal fixation after achieved the acceptable length or contact of bone transport fragment allowed early motion of the joint to avoid stiffness. Good to excellent functional outcomes was achieved in majority of patients.

Conflict of interest declaration

The authors hereby declare no personal or professional conflicts of interest regarding any aspect of this study.

Funding disclosure

This was an unfunded study.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent

Informed consent was obtained from all individual participants included in the study.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.jcot.2018.04.015.

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