Functional outcomes of the failed distal tibial fracture fixation combined with ankle arthritis salvaged by retrograde intramedullary non-vascularized fibula graft with a circular external fixator

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Abstract

Background
Management of distal tibia fractures with articular involvement is a therapeutic challenge. The Ilizarov ring fixator provides multiplanar stability, helps in the correction of angulation, rotation at the non-union site and promotes ankle fusion much effectively in conjunction with bone graft special if it adds intramedullary strut as retrograde intramedullary non-vascularized fibular graft.

Patients and methods
This study was carried on in Mansoura university hospital between January 2012 and December 2017 including eleven patients ,9 males and 2 females with an average age of 32.3 years (range 22 - 55). The right side was affected in 6 patients and left sides affected in 5 patients. All the patients had major trauma to the leg and ankle. All were not able to walk without assistive devices and all were operated several times before with an average of 4.8 (ranging: 3-9) surgeries per patient, 3 cases had foot drop, the average preoperative LLD was 3.4cm (Ranging: 2.5 - 6cm).
We used the lateral trans-fibular longitudinal approach of the ankle. The ankle was opened laterally with curettage articular surface of the distal tibia and talus and subtalar joint. The tibial bone defect site was meticulously derided with opening of the medullary canal, then preliminary intramedullary half pin fixation, frame application, sequential reaming, and fibular graft was threaded on guide wire and hammered to bridging the subtalar, the ankle joints and the tibial bone defect.

Results
The follow-up period after removal of the frame ranged from 20 months to 60 months with an average of 36 months. The total treatment time of frame application ranged from 6 months to 12 months with an average of 8.5 months. The outcome was assessed by bony union at the tibial defect and the ankle outcome was assessed by The American Orthopaedic Foot and Ankle Society (AOFAS) which ranged from 58 to 87 with an average of 76. According to this scoring system the results were excellent in 3 cases, good in 6 cases and fair in 2 cases. All the patients had united equal length tibiae with stable painless plantigrade feet which were satisfying enough to them special to those with foot drop and multiple failures before.

Conclusion
The results of this study suggest that retrograde intramedullary non-vascularized fibula graft with a circular external fixator is an attractive one stage surgical alternative for the treatment of failed distal tibial fractures fixation combined with ankle arthritis and can reliably achieve bony union and sound fusion in shorter duration with a satisfactory clinical outcome.

Keyword
Distal tibial fracture; ankle arthritis; external fixator.

Introduction

Management of distal tibia fractures, with or without articular involvement, is a therapeutic challenge[1,2,3]·The main objectives of orthopedic surgeons is to restore the tibial anatomy, joint congruity ,soft tissue coverage with early mobilization. These objectives can be attained by several techniques as; traditional open reduction and internal fixation (ORIF), external fixation with or without limited internal fixation, intramedullary nailing or, more recently, minimally invasive plate osteosynthesis [4,5]

Despite progress of surgical procedures, outcomes are not always excellent and complications affect 20–50% of patients [6].And the situation may more

complex due to high velocity injuries, bone defect, infection and soft tissue envelope disruption [7]. The prevalence of nonunion in closed tibial fractures is 2.5% and it increases 5–7-fold for open fractures with gross contamination and extensive soft tissue damage [8].

The ankle injury and subsequent arthritis may occur as result of primary trauma or as consequence of surgical treatment making the scenario darker.

The presence of other problems as soft tissue defect, foot and ankle deformities, nerve injuries, leg length discrepancy (LLD) and sudeck's dystrophy in addition to the tibial nonunion and ankle arthritis put the orthopedic surgeon in challenging situation with different scenarios of management either simultaneous in one stage or consecutive multiple procedures.

The Ilizarov ring fixator provides multiplanar stability, helps in the correction of angulation, and rotation at the nonunion site much effectively, Thus the Ilizarov is mostly used as a salvage option in the treatment of complex nonunion of tibia and ankle fusion [8,9, 10].

The non-vascularized fibula is considered as one of the most common sources of cortical autograft, which have been used to fill a defect and buttress construct with a good mechanical support and high osteogenic potential[11]. It can be used as an intramedullary graft for tibiocalcaneal fusion with success either alone [12] or with blade plate to take advantage of mechanical and biological stimulus for healing [13].

In our technique we used a long retrograde intramedullary non-vascularized fibular graft to bridge the subtalar, ankle joints and the tibial defect in combination with the circular fixator that exert acute shortening and compression distally with proximal corticotmy for later on lengthening to attain equal length legs with stable painless plantigrade feet, minimal soft tissue disruption and early return to work.

The aim of the present study was to assess the functional results of long retrograde intramedullary non-vascularized fibula graft with a circular external fixator in the treatment of combined distal tibial nonunion with ankle arthritis.

Patients and methods

Between January 2012 and December 2017, 11 patients with non-united fracture of the distal third of the tibia with a bone defect associated with post traumatic ipsilateral ankle arthritis were prospectively treated in our institution by long retrograde intramedullary non-vascularized fibula graft with a circular external fixator. Informed consent was obtained from all individual participants included in the study .The study was performed in accordance with the Declaration of Helsinki.

Data collected in this study included: age, gender, and mechanism of injury, type of fracture, history of previous fixation, reconstructive options and the mean operative time. Nine patients were males and two patients were females with the mean age of 32.3 years (range 22- 55), right side was affected in 6 patients and left side affected in 5 patients. All patients were not able to walk without assistive devices due to pain, associated deformities and nerve injuries.

Preoperative clinical and radiographic assessment was done including the detailed vascular and neurological status distal to injury, the skin condition The ulcers assessed to know either were deep enough to expose the subcutaneous tissue and did not reach the bone or not .The leg, ankle and the foot were examine for associated deformities, foot drop, Eqinocavovarus deformity, leg length discrepancy (LLD) and Sudeck's Dystrophy.

All patients included in this study had history of high velocity trauma (8 cases had motor car accidents and 3 cases had fallen from height). 9 cases had open fracture with different severity of soft tissue injury. All the cases were operated several times before presentation to us with an average 4.8 (ranging: 3-9) surgeries per patient either soft tissue coverage procedures (partial, full thickness skin grafts, rotational flaps or distant pedicle flap) or bony reconstruction (internal or external fixation) or both. The time interval between primary injury and our procedure ranged from 5 -14 months (mean 6 months). The average preoperative LLD was 3.4cm (ranging: 2.5-6cm). Out of 11 cases we had 3 cases with foot drop and eqinocavovarus deformity of the foot and ankle , one case was due to common peroneal nerve injury and the other two cases were due to sever soft tissue injury in lower tibia . We exclude the patients with active deep infection of the bone or soft tissue, severe injury to the posterior tibial nerve with absent plantar sensation and inadequate patient compliance.

Operative technique: (Fig. 1)

All The patient done in Supine position on translucent table and tourniquet was applied to the proximal thigh, removal of external fixator and kirschner wire were done (if present) before draping. We used a lateral trans-fibular longitudinal approach of the ankle which extended distally to the subtalar joint, removal of the hardware. The ankle was opened laterally with

meticulous debridement of the fibrous tissue and removal of the articular surface of the distal tibia and talus till bleeding bone with preservation of the talar bone stock as much as we can. Also, subtalar joint was opened and articular cartilage was shaved and cleaned, the tibial bone defect site was exposed from the same approach and was meticulously derided (excision of the sclerosis bone and fibrous tissue) with opening of the medullary canal. We harvested a 15-20cm of the distal fibula with subperiosteal dissection with preservation of peroneal artery. The fibular graft was prepared in such a way that transverse cut was done at the metaphyseo-diaphyseal junction, and the distal metaphyseal part was macerated and used as cancellus bone graft and the diaphyseal part was cleaned from soft tissue, so as it is ready to be used as intramedullary strut graft.

After application of cancellus bone graft obtained from the fibula into the ankle fusion site the foot was held under the tibia in aligned position with correction of deformity of hind foot acutely, the foot was kept in neutral dorsiflexion and 10 degrees valgus. The foot position was maintained by insertion of a long (25cm) 6 mm half pin inserted through a trajectory point in the sole which lies in the intersection of 2 lines, in sagittal plane, the 1st line is drawn from the 2nd toe to the center of the heel, in coronal plane, the 2nd line is made at the junction of the anterior and middle third of the heel pad passing through the calcaneous , subtalar joint, the talus, the ankle joint ,the distal tibial metaphysis, the tibial bone defect and the proximal tibial bone after proper alignment using image intensifier in both anteroposterior and lateral projections.

Then, the preassembled Ilizarov circular fixator was applied with 3 tibial rings, one 5/8-calcaneal ring and ½ rings in the forefoot which applied in a standard fashion except the distal tibial ring. Then the transcalcaneal half pin was removed and replaced by a flexible intramedullary guide wire and sequential reaming was carried on starting with size 8 mm and progressed up to the measured diameter of the fibula without the need for over reaming to allow good press fit of the graft inside the medullary canal. The graft was passed over the guide wire and under the fluoroscopic control, the graft was hammered with the help of long 5 holes Rancho cube which acts as cannulated bone impactor till reaching the final position and become flush with the inferior surface of the calcaneus, lastly, the guide wire was withdrawn.

Scanogram (CT) was done to verify the equality of both lower limbs. The frame was retained until fracture union and adequate consolidation of the regenerate .Radiological healing was considered when there was bridging callus at least in 3 of 4 cortices. Dynamization of frame were done when radiological healing was achieved and the patient was allowed to weight bearing on the extremity. Then the frame was removed and the limb protected above knee plaster cast for 6 weeks then in a functional brace for 6 weeks.

The distal tibial ring was fixed to bone of the distal tibial metaphysis and intramedullary fibular graft with transfixing 1.8mm Ilizarov wires. Acute compression at the ankle and subtalar joints was applied by the distal ring and foot frame circular fixator, followed by acute compression at tibial bone defect through acute limb shortening to allow more bony contact between the two ends (or allow threading of the fibula into the proximal tibial segment in the cases with large bone defect to be completed later by bone transport and to avoid much acute shortening). Proximal tibial corticotmy was done to allow gradual limb lengthening (+/- bone transport) later on.

The operative time ranged from 120 minutes to 160 minutes with an average of 135minutes. Postoperative radiographs were taken to assess the bony alignment, deformity correction, completeness of corticotmy and placement of wires and pins. The patients were allowed toe-touch weight bearing within 24 hours and mobilization of the nearby joints were encouraged to prevent contractures. Pin site care and hygiene was taught to all patients. Distraction was started 8th postoperative day at the rate of 1 mm per day four increments as presented. Postoperative care were carried on at outpatient clinic with regular followed up for assessing progress of the soft tissue and bone transport, formation of regenerate in radiographs, any infection, loosening of wires and neurovascular deficit. Radiographs were taken every 2 weeks till correction of LLD and then at 4 weeks interval till consolidation and the frame removal. The distraction rate was modified in cases where weak regeneration or premature regenerate consolidation. Poor consolidation of the regenerate was treated by encouraging weight bearing and alternate compression- distraction (accordion maneuver).

Results

The outcome was assessed by the bony union at the tibia defect site determined using plain film radiography with AP, lateral, views and the ankle outcome was assessed by The American Orthopaedic Foot and Ankle Society (AOFAS) [14] after external fixator removal.

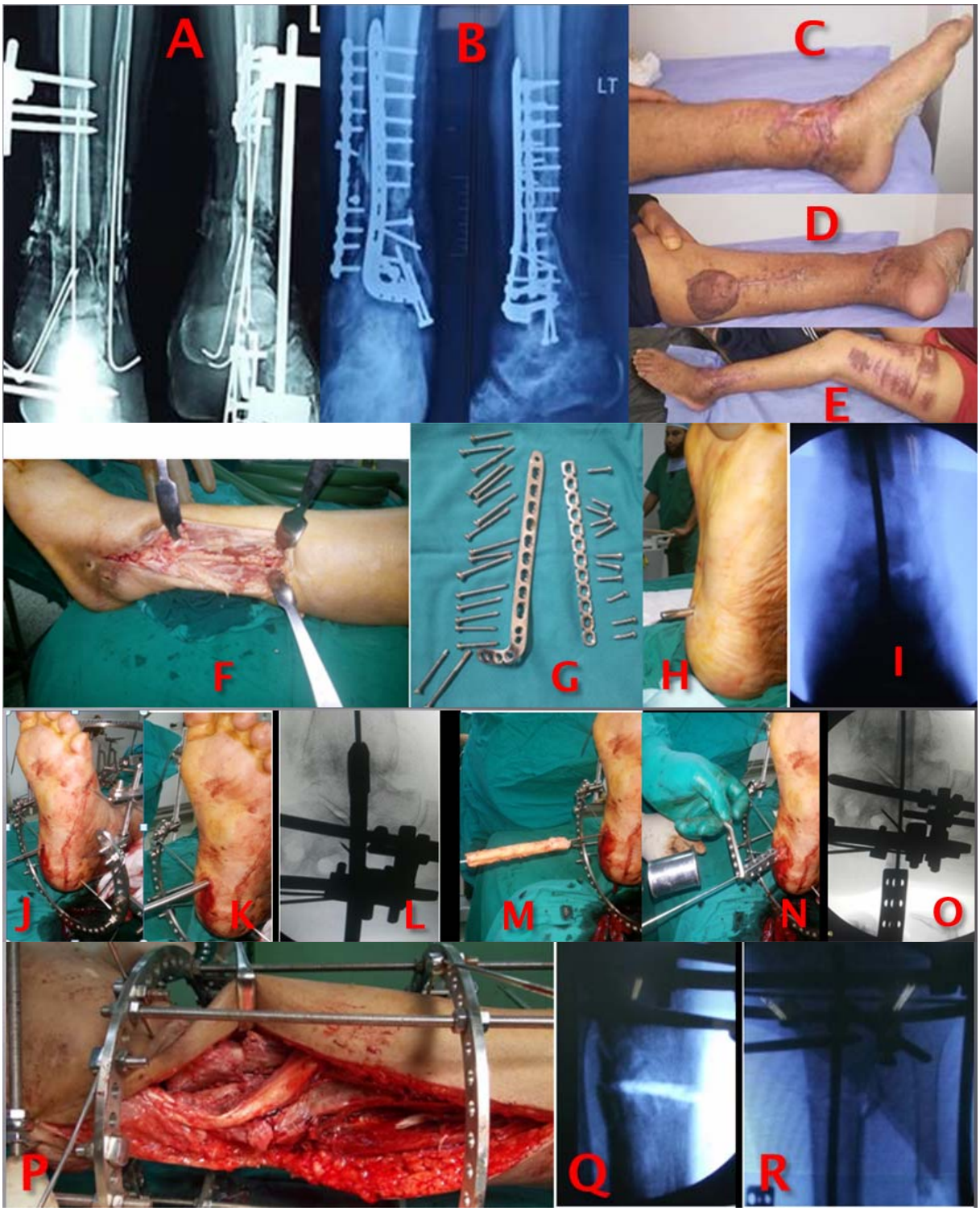

Fig 1: surgical techniques from different cases, **A&B:** Preoperative example x-rays of internal fixation and external fixator cases, **C,D&E:** Preoperative clinical photos of previous soft tissue coverage attempts, **F:** lateral approach**, G:** retrieved hardware**, H& I:** clinical and image intensifier photo of preliminary intramedullary half pin fixation **, J:** guide wire application after frame application, **K&L:** medullary reaming **M,N&O:** fibular graft hammering, **P:** clinical photo of acute shortening with the fibula seen intramedullary **Q&R:** the proximal tibial corticotmy

The follow up period after removal of the frame ranged from 20 months to 60 months with an average of 36 months. The total treatment time of frame application ranged from 6 months to 14 months with an average of 8.5 months according to the amount of tibial bone defect and subsequent lengthening which ranged from 3-7cm with an average of 5.5cm and progress of fracture healing.

All the cases were subjected to acute shortening and lengthening (case in fig. 2) except 3 cases which had bone effect more than 4cm, in which partial acute

shortening were done to allow telescoping of the fibular graft into the medullary canal of proximal tibial bone segment followed by bone transport until docking followed by lengthening till equalization of the both lower limbs.

All the fibular grafts has been osteointergrated in host bone with gradual disappearance (Shadows or Ghosts) without any case with deep infection or sequestration, two cases had fracture of the fibular graft one at subtalar joint (3 months post frame application) and other at lower end of medullary canal of the proximal tibial segment (5 months post frame application) without affection fusion or bone healing rates but with faster resorption of the fibula, both cases occurred when the patient started to increase the partial weight bearing on affected foot, sound and painless fusion was achieved in all the cases and sound bone healing was attained at tibial bone. One case had stress fracture at half pin insertion in the diddle third of the tibia 3 months after the frame removal which was managed conservatively in above knee cast and healed without surgery.

Skin breakdown had occurred postoperatively in four cases (those had bone defect 4cm or more) because of adherent thin flaps to underlying bone and fibrous tissue and because of the acute shortening (+/- bone transport) these ulcer healed conservatively in 6-8 weeks period without other skin coverage option. Pin tract infection occurred in 7 cases that improved with local measures around the pins and short course of systemic antibiotics. All the patients were able to ambulate unaided except one case that used a unilateral cane. LLD was corrected in all the patients with bone defects and /or shortening.

The American Orthopaedic Foot and Ankle Society (AOFAS) [14] score for the ankle and hind foot in our study ranged from 58 to 87 with an average of 76. According to this scoring system the results were excellent in 3 cases, good in 6 cases and fair in 2 cases.

All the patients had united equal length legs with stable painless plantigrade feet which were satisfying enough to them special to those with foot drop and multiple failures before.

Discussion

Distal tibial non-unions are difficult to treat, and the small distal fragment presents a major challenge for the surgeon [15]. The management of distal tibia fracture is difficulty and has a high complication rate. This complications ranging from 20% to 50% of patients and were mostly infectious or cutaneous problems and nonunion or altogether [16,5,6]. There is a correlation between complication rate and initial fracture severity in the same way, high fracture severity, complications or malunion were associated with poor clinical results [17,18]. Earlier studies have used ankle arthrodesis as a salvage procedure [19,20], while more recent studies have attempted to preserve the integrity of the ankle joint [16,21].

Ankle arthrodesis by external fixation has been advocated by many authors for patients with infection or complex ankle pathology [22,23]. The Ilizarov method has been used by numerous surgeons to equalize LLD through tibial lengthening and achieve ankle arthrodesis [28, 26, 29, 27]. Performing a tibial osteotomy in the setting of an ankle fusion has been thought to enhance healing at the arthrodesis site [24].

In our study we had multiple overlapped problematic and complex situations in somatically and psychologically frustrated patients who had suffer multiple revision surgeries and failures for long periods. Beside the non-united tibia with bone defects and the ankle arthritis they had one or more of the following: foot drop, Equino-Cavovarus deformity, leg length discrepancy (LLD) and Sudeck's Dystrophy.

Our point of view in such cases was to manage all patients' deformity in one stage rather than staged procedures for better psychological impact on such patients with rapid recovery and return to the normal daily activities. In our previous study we used retrograde intramedullary nonvascularized fibular graft with circular frame in the management of unstable Charcot joint with promising results so we used the same principle with a longer fibula to cross the bone defect and to share in the tibial bone healing around the gap and adding more intramedullary strut with the external fixator.

Our procedure provided: hind foot deformity correction through the ankle fusion, the mid foot deformity correction by the circular fame either acute or gradual, the tibial bone defect management through the intramedullary strut and acute shortening, the soft tissue coverage enhancement through acute shortening and later on lengthening (+/- transport), no donner site morbidity as no local or distant soft tissue flaps were used and the bony graft (fibula) has been harvested from the same approach.

Bone union was achieved in all cases of tibial bone defect and the functional outcome AOFAS was rated good in over 81 % (9 out of 11 cases) of patients and all patients were able to walk again without assistive devices and they all were pain free at a mean follow-up of 36 months.

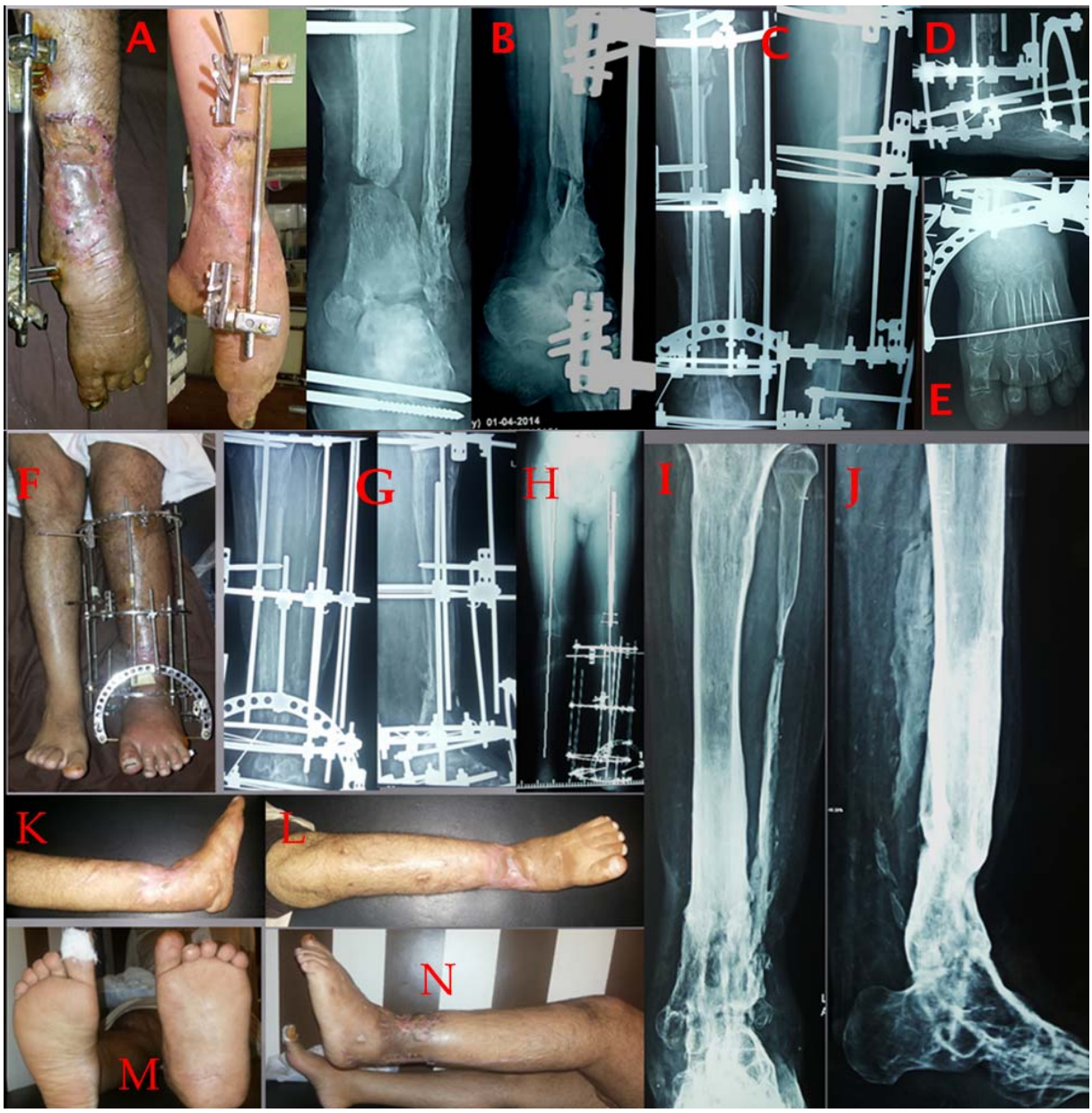

Fig. 2: A 35 years old male patient suffered from high velocity motor car accident 1 year before, He had Gustilo grade III open fracture both bone of left leg which was managed by Debridement External fixator, K-wire and four trial of Skin grafting; **A&B :** clinical and x-ray photos show preoperative deformity, skin graft, and Ex. Fix., bone defect and ankle arthritis, **C,D&E:** postoperative x-ray of the leg , ankle and foot **F,G&:** clinical and x-ray photo after lengthening **, H:** Scanogram measurement for equalization of both lower limbs, **IJ:** Anteroposterior and lateral x-ray views 3 years post operatively ,**K,L,M&N:** clinical photos show final outcome from medially ,anterior, planter and later aspects.

Laklouk et al. reported on their experience with 13 cases of failed internal fixation, of which three had an infected non-union. Following treatment with Ilizarov external fixation, union was achieved in all cases with a mean duration of external fixation of 146 days [21].

Eralp et al. also treated 13 cases of infected non-union of the juxta-particular region of distal tibia. The Ilizarov fixator was used in 12 cases, and the Taylor Spatial Frame was used in one Union was achieved in all cases, with a mean time in external fixation of 198 days and 12 patients had good or excellent results when the functional outcomes. However, five patients (38%) required an ankle arthrodesis [15].

Arvesen et al [25] assessed the efficacy of hexapod external fixation for the treatment of distal tibial non-unions with associated complex deformities. They reported a 94% union rate and reduced a mean 18 degree pre-operative deformity to less than 5 degrees after. Functional outcomes were not reported. Hexapod external with the mean duration of external fixation for the septic cases was 274 days, and for the aseptic cases, the mean duration of external fixation was only 137.

Other author reporter similar result of the limb salvage reconstruction of the ankle with fusion and simultaneous tibial lengthening using the Ilizarov/Taylor spatial frame but with increased External fixation index compared to our study table 2.

Table 2: Literature comparison for tibial lengthening with ankle arthrodesis

Study	Number of patients	Lengthening (cm)*	External fixation index (days/cm)	Ankle fusion rate (%)	Lengthening complications
Rochman et al. [26]	8	4	54	87	Regenerate collapse angular deformity, delayed union of regenerate
Tellisi et al. [27]	12	5.5	54	84	None
Katsenis et al. [28]	11	4	76	100	Pin site infection requiring exchange, premature consolidation
Sakurakichi et al[29]	6	4.1	35-144	100	None
Fragomen et al [30]	24	4.3	68	83	Regenerate collapse valgus, knee flexion contracture
Current study	11	5	46.3	100	Pin site infection, stress fracture tibia managed conservatively

In our study were had similar results as there were 9 (81%) out of 11 cases with good to excellent results with a mean duration of external fixation of 8.5 months (255 days) with an average bone lengthening of 5.5 cm and the mean external fixator index was 46.3 day /cm .

We think the shorter duration in frame in spite of the mixed complex tibial and ankle pathology may be due the strut intramedullary osteoconductive and osteogenic properties of the non-vascularized fibula.

Conclusion

The results of this study suggest that retrograde intramedullary non-vascularized fibula graft with a circular external fixator is an attractive one stage surgical alternative for the treatment of failed distal tibial fractures fixation combined with ankle arthritis and can reliably achieve bony union and sound fusion in shorter duration with a satisfactory clinical outcomes.

Conflict of Interest: The authors declare that they have no conflict of interest, there was no funding source.

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