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ORIGINAL STUDY

Management of massive posttraumatic bone defects in the lower limb with the Ilizarov technique

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Massive bone defects have been treated by various methods with variable success rates. The Ilizarov technique has been advocated as a preferred method for treatment of large segmental defects.

Twenty five patients with massive post traumatic bone defects of the lower limb (22 tibiae, 3 femurs) were treated using Ilizarov's technique. After radiological evaluation, the patients were subjected to bone transport. Bifocal osteosynthesis was performed in all except those needing > 12 cm of bone transport. Distraction was started between day 4 and 7 at the rate of 1 mm per day in four increments.

All were males with a mean gap of 8.9 cm (range : 5-17 cm), mean age of 28.24 years (16-40) and having undergone a mean of 2.6 previous surgeries. Mean time in Ilizarov frame was 8.8 months and external fixator index was 0.98 months. Mean duration of follow-up after frame removal was 23.5 months.

Union was achieved in 23 (92%) cases. Bone grafting was required in 9 (36%) According to ASAMI criteria, bone results were excellent in 13, good in 1, and poor in 11 patients. Functional results were excellent in 6 patients, good in 9, fair in 4, and poor in 6 patients. A total of 72 complications occurred (2.88 complications per patient). Union was achieved in all except two patients.

The Ilizarov external fixator offers a limb salvage solution even in large bone defects but the surgeon should set realistic goals both for himself and his patients while offering this method of treatment.

Keywords : gap nonunion ; Ilizarov ; bone transport ; bone defect.

INTRODUCTION

The increasing incidence of high-velocity trauma with massive damage to bone and soft tissues poses a major challenge. These high-velocity injuries may lead to problems such as pseudoarthrosis, deformity, limb length discrepancy, and problems associated with soft tissue healing and coverage (*21*). Bone defects can result from the trauma or from subsequent debridement for sequestration and infection. Bone defects have been treated by various methods including cancellous bone grafting (*10,21*), Papineau-type open cancellous bone grafting (*13*)

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and vascularized fibular grafts (*21*). While the first two methods are suitable only for small gaps, a vascularized fibula, which may be considered for larger gaps, is technically demanding. Considerable success has been reported with the Ilizarov technique for treatment of bone gaps, and it has been advocated as a preferred method for treatment of large segmental defects (*9,10,16*).

We report our experience in treating massive post-traumatic bone defects using bone transport by the Ilizarov technique where traditional orthopaedic techniques are often inadequate.

MATERIALS AND METHODS

Twenty five patients with non-union and > 5 cm of bone loss in tibia or femur underwent treatment by bone transport using the Ilizarov technique. At presentation, a full history was obtained for details of the initial injury and previous surgical interventions. The patients were examined for presence of shortening, neurovascular deficiency, condition of soft tissue ; active infection if any, and function of relevant joints was documented. Radiological evaluation was done to determine the fracture pattern, plane of deformity, alignment and to look for signs of osteomyelitis. Patients were further classified as having an actively infected non-union if there was a discharging sinus and/or a positive culture swab from tissue obtained at debridement. The patients were informed about the approximate duration of treatment and the associated complications prior to reconstructive surgery.

Patients with active infection were subjected to radical debridement involving resection of nonviable bone ends before application of the frame. Intra-operative cultures were sent and antibiotics were administered accordingly.

Frames were assembled preoperatively for all patients and modified per-operatively if required. In patients with active infection the site of non-union was exposed and devitalized tissues including unhealthy bone ends were removed. Sclerotic bone ends were excised and the medullary canal was opened. Punctate cortical bleeding was used to determine the completeness of bone debridement. The frame was applied with a varying number of rings, depending upon the size of the limb, site of lesion, and size of bone fragments. The intercalary segment was stabilized using either wires or a combination of wires and Schanz pins. A foot assembly was used in those patients where the distal tibial fragment was short or where there was a pre-existing equinus deformity. Bifocal osteosynthesis was performed in all except those needing > 12 cm of bone transport. Intramedullary wire was used to guide the transported fragment in two cases to prevent axial deviation. Fibular osteotomy was done in patients in which the fibula had united with malalignment of tibial fragments. Corticotomy was performed in all cases at the same time as frame application.

Postoperative radiographs were taken to assess the corticotomy and placement of wires and pins. The patients were allowed toe-touch weight bearing within 48 hours and mobilization of the relevant joints were begun to prevent contractures. Emphasis was laid on active and passive mobilization of the relevant joints. A foot sling was used in patients where a foot assembly was not applied. Pin site care and hygiene was taught to all patients. Distraction was started between day 4 and 7 at the rate of 1 mm per day in four increments. The patients were discharged as per wound condition and when they were comfortable with mobilization and distraction regimes. They were followed up regularly in the outpatient department and assessed for any infection, loosening of wires, for progress of bone transport, formation of regenerate in radiographs, docking site problems, and neurovascular deficit. Radiographs were taken every 4 weeks until docking and then at 6 weeks interval till consolidation and frame removal.

The rate was modified in cases where slow regeneration or premature regenerate consolidation occurred. Poor consolidation of the regenerate was treated by encouraging weight bearing and alternate compression-distraction (accordeon maneuvre). Complications like pin tract infections, wire loosening (re-tensioning) and poor regenerate consolidation were managed on an outpatient basis but severe pin tract sepsis, major frame reconstruction for malalignment, change of wires/pins, and bone grafting required short periods of hospital stay.

Once docking was achieved, the frame was retained at least until fracture union and adequate consolidation of the regenerate. Iliac crest bone grafting was used in patients with docking site non-union. If there was evidence of union radiologically, the frame was retained for an additional period equal to the time from frame application to the appearance of signs of union. Radiological healing was considered when there was bridging callus at least in 3 of 4 cortices. Once radiological healing was achieved, the connecting rods were loosened (dynamization of frame) and the patient allowed weight bearing on the extremity. If the patient could tolerate weight bearing, the frame was removed and the limb protected in a functional brace for a further period equal to the time from application of frame to its removal.

Bone healing and the functional results were assessed according to criteria given by ASAMI (Association for the study and application of the method of Ilizarov) (*2,6,12*). Bone healing was evaluated based on union, infection, deformity, and limb length discrepancy (table I) and classified as excellent, good, fair and poor (table I).

Lengthening index (external fixator index) was calculated by dividing the frame-keeping period in days by the length of the regenerated bone (cm).

The functional result was evaluated according to 5 criteria which include limp, range of motion of adjacent joints, sympathetic dystrophy, and return to activity, and classified as excellent, good, fair and poor (table II).

RESULTS

All patients were male with a mean age of 28.24 years (range : 16-40 years). There were 22 tibial and 3 femoral bone defects. Of these, 12 had active infection. The median time between injury and application of the frame was 9 months, and the mean number of previous surgeries was 2.64 (range : 1-5). The mean length of bone defect at the time of frame application was 8.9 cm (range : 5-17 cm). Two patients underwent split skin grafting and one patient underwent a free flap prior to the frame application. The site of corticotomy was the proximal tibia in 18 patients, the distal tibia in 1 and the distal femur in 3 patients. Three patients had both a proximal and distal tibial corticotomy. The mean follow-up time from removal of fixator to the last clinic visit averaged 23.5 months (range : 15-60 months). The mean time in Ilizarov frame was 8.8 months (range : 7-18 months) and mean external fixator index was 0.98 months/cm.

Union was achieved in all except two patients (92%) (fig 1-3). Both of these patients remained in

Table I. — Results using the scoring system of the Association for the Study and Application of the Methods of Ilizarov (ASAMI)

Bone results	Criteria	No. of patients
Excellent	Union, No infection, Deformity < 7^0, Limb length discrepancy (LLD) < 2.5 cm	13
Good	Union + Any two of the following Absence of infection < 7^0 deformity LLD < 2.5 cm	1
Fair	Union + Any one of the following Absence of infection < 7^0 deformity LLD < 2.5 cm	0
Poor	Non-union/Refracture/ Union + Infection + Deformity > 7^0 + LLD > 2.5 cm	11

Table II. — Functional Results

Functional results	Criteria	No. of patients
Excellent	Active, No limp, Minimum Stiffness (Loss of < 15^0 knee extension/ < 15^0 ankle dorsiflexion), No Reflex Sympathetic Dystrophy (RSD), Insignificant pain	6
Good	Active with one or two of the following Limp Stiffness RSD Significant Pain	9
Fair	Active with three or all of the following Limp Stiffness RSD Significant Pain	4
Poor	Inactive (Unemployment or inability to return to daily activities because of injury)	6
Failure	Amputation	0

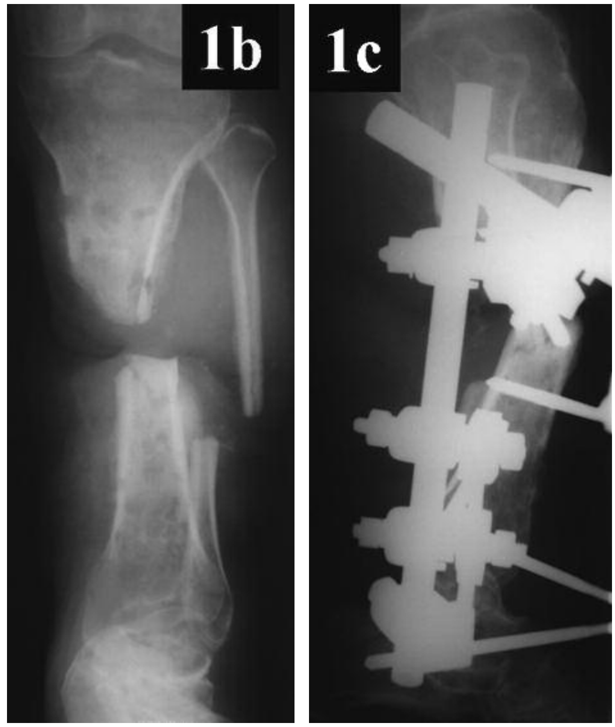

Fig. 1. — a : Initial radiograph following infected external fixator removal with a gap of 17 cm with loss of a fibular segment ; b : Reapplication of external fixator at another institution 3 weeks after index surgery. Note marked soft tissue contraction with short limb ; c : Fixator got infected and loose within 3 weeks and had to be removed.

non-union at the docking site despite three attempts at bone grafting of the docking site. Infection was controlled in all patients except one. Bone grafting was done in 9 of 25 cases (36%). Eight were necessitated due to skin invagination at the docking site ; hence at the time of freshening at the docking site, bone graft was added. Autogenous iliac crest graft was used in all.

Complications

A total of 72 complications occurred in 25 patients, an average of 2.88 complications per patient. The most common complication was pin tract infection which occurred in 20 patients (80%). Seventeen of these responded well to local care and antibiotics, two patients required a change of wire and one patient required abscess drainage.

The next most common complication was ankle and knee stiffness in 18 patients (72%). More than 15^0 loss of ankle dorsiflexion occurred in 14 patients. Loss of range of motion of the knee occurred in 8 patients, with one patient having 40^0 of knee flexion deformity and two patients with a 15^0 flexion deformity. The other 5 patients had an extensor lag of < 20°.

Skin invagination occurred at the docking site in 8 patients (32%) ; it was treated by removing the invaginated soft tissue, freshening of bone ends and autogenous iliac crest bone grafting.

Poor regenerate formation was seen in 7 patients (28%). They were treated by slowing the rate of distraction (0.5 mm per day in 2 increments) and encouraging weight bearing. All of them later had good regenerate consolidation. Axial deviation was seen in

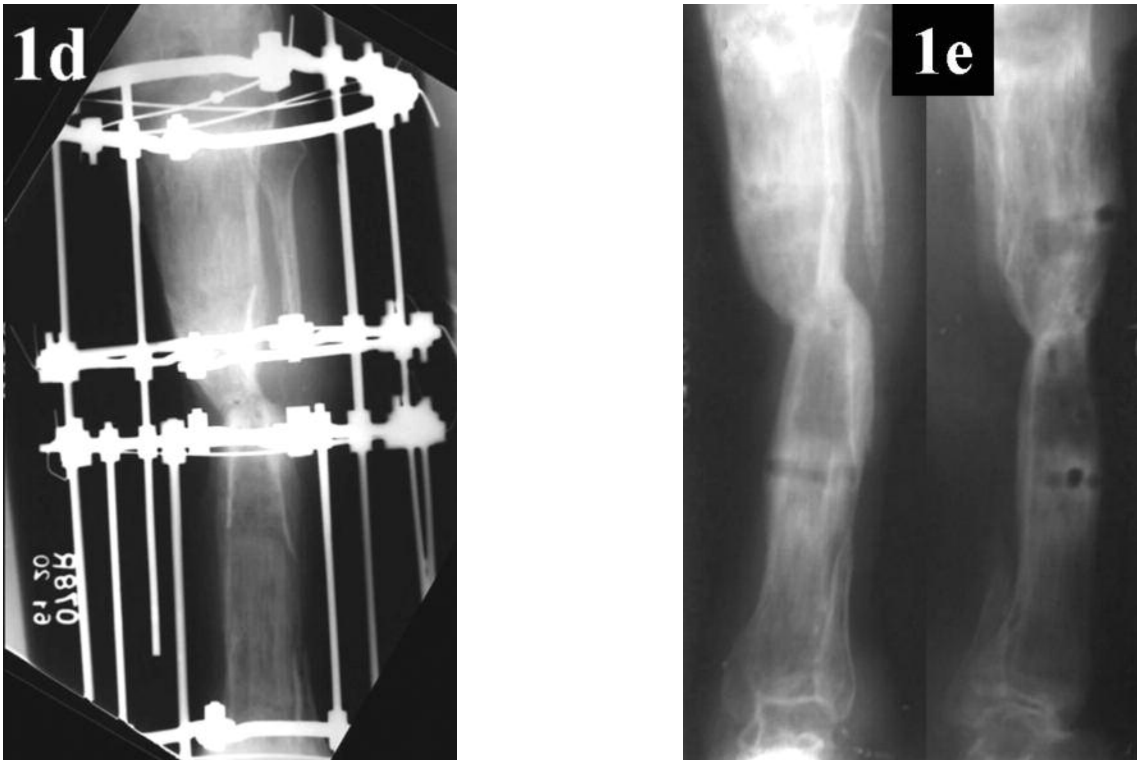

Fig. 1. — d : Following trifocal osteosynthesis with proximal tibial and distal tibial corticotomy with bone transport at both ends with docking at fracture site ; e : Following fracture union and regenerate consolidation. Ilizarov frame removed.

6 patients (24%) and was corrected by frame adjustment. Refracture at the docking site occurred in 4 patients ; they were treated by reapplication of a fixator and bone grafting. The refracture occurred at an average of 5 months after frame removal ; two patients had a history of significant trauma while 2 had trivial falls. All of these patients progressed on to union.

Wire cut-through was seen in 3 patients who had highly osteoporotic bones ; they were treated by change of wire. Regenerate fracture was seen in 1 patient (4%). This patient was overenthusiastic and discarded the brace prematurely against medical advice. He was treated in a cast and went on to healing satisfactorily.

A pseudo-aneurysm was seen in one patient who complained of persistent pain and bleeding from a pin tract site ; the diagnosis was confirmed by Doppler and angiography. The offending pin was removed and the pseudo-aneurysm ligated. The patient recovered uneventfully and is doing well at 2 years follow-up.

As per ASAMI protocol (*6*), a bone result cannot be graded as excellent unless union is achieved without the use of a bone graft. This can cause an otherwise excellent bone result to be classified as poor due to use of a relatively simple procedure for accelerating healing (*6*). Bone results were found to be excellent in 13 patients (52%), good in 1 patient (4%), fair in none and poor in 11 patients (44%). But if bone grafting as an indicator of poor bone result is ignored, 22 patients (88%) had an excellent or good bone result (table I).

According to the criteria given by ASAMI (*6*), 6 patients had an excellent functional result (24%), 9 patients (36%) had a good, 4 patients (16%) had a fair and 6 patients (24%) had a poor functional result (table II). Six patients did not return to any

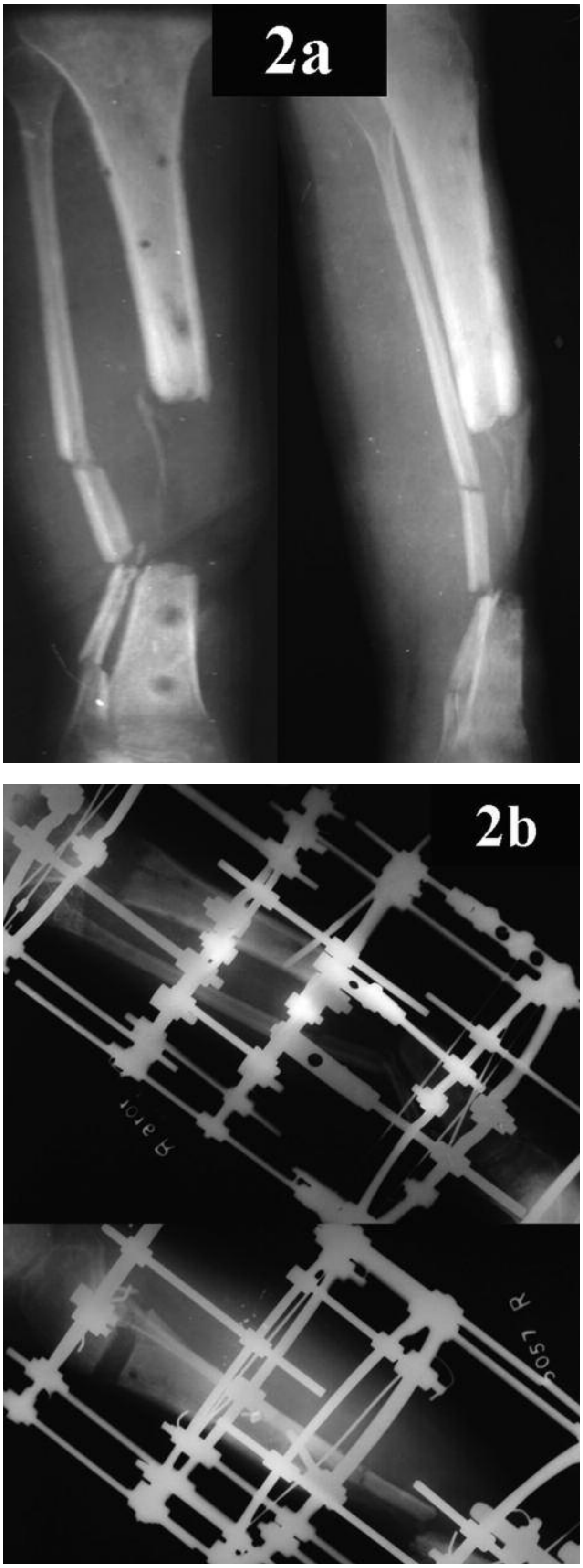

Fig. 2. — a : Initial radiograph following previous external fixation showing a bone defect ; b : Bone transport was done with proximal tibial corticotomy ; c : Radiograph after Ilizarov removal. Sound union was achieved with consolidation of the regenerate.

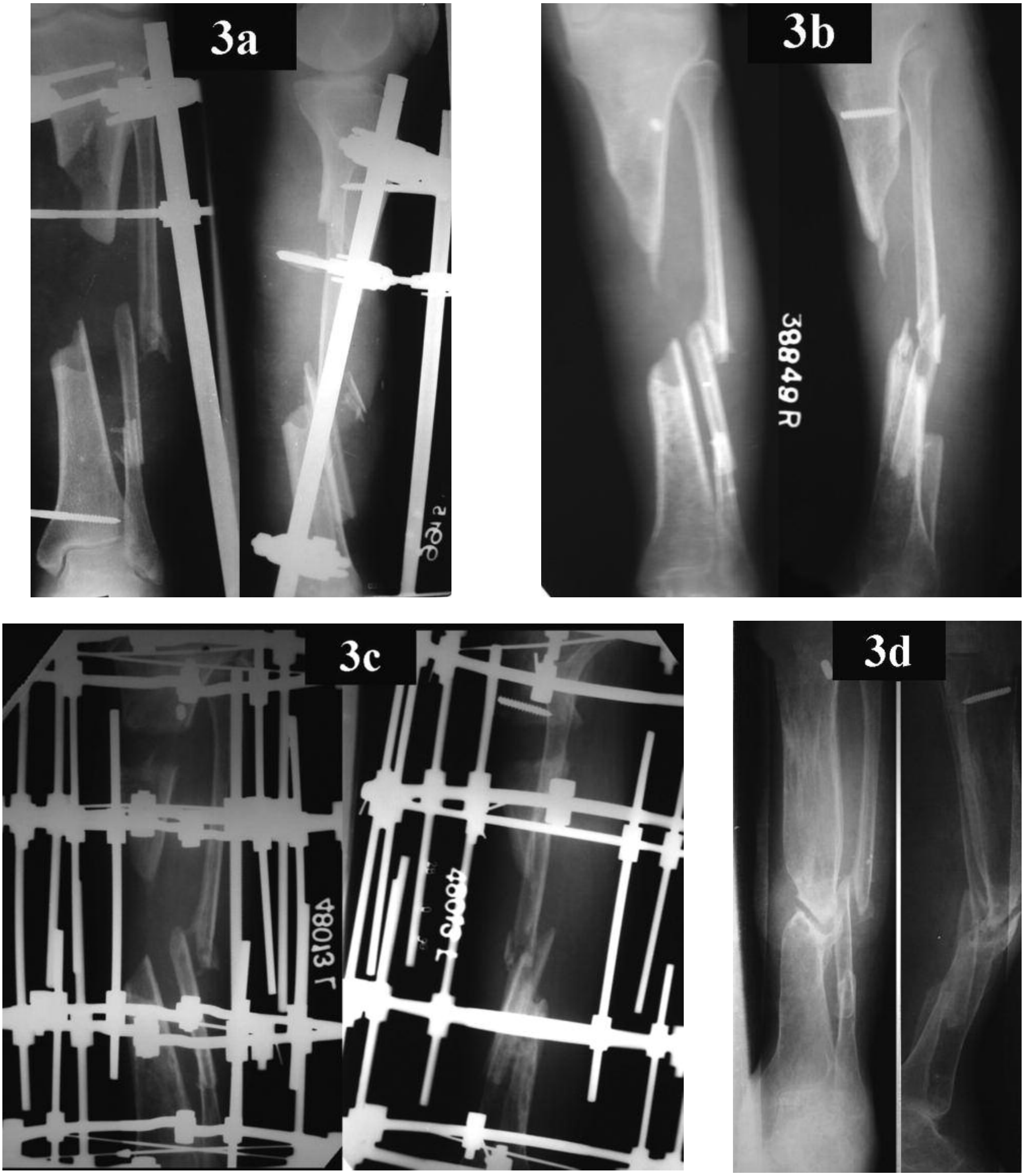

Fig. 3. — a : Radiograph at presentation with external fixator in situ. The gap is much more than what is apparent since there is a segmental fracture of the fibula with considerable overlap at both fracture sites ; b : The pins were infected and the fixator was removed. Note the bone defect and tapering fracture ends ; c : The patient was treated by bone transport by a proximal tibial corticotomy ; d : Fracture site remained in non-union despite repeated bone grafting. The patient refused any more surgical intervention but remained mobile with a brace.

work at all, which included 2 patients where union was not achieved, 3 patients with significant pain and joint stiffness and one with mental depression. Five patients (20%) returned to their original work while 14 patients (56%) required a change of profession. Seventeen patients (68%) had a noteworthy limp, fifteen patients (60%) had significant joint stiffness, and 5 patients (20%) had significant pain resulting in reduced activity (table II).

DISCUSSION

Reconstruction of segmental bone defects remains a challenge. Autologous bone graft is good for small defects, but if the defect is large, graft may have to be harvested from more than one site, adding to the morbidity of the patient. Also there is a limit to the quantity of autologous bone graft that can be procured, which may not be enough for large defects. Cierny *et al* (*5*) compared the results of treating segmental tibial defects using massive autologous bone graft and Ilizarov bone transport and found bone transport to be superior considering both bone and functional results.

Vascularized fibular bone grafting has been successfully used to bridge bone defects in the arm and forearm (*19*) but several drawbacks exist in its use in the lower extremity, including a technically demanding procedure, size limitations of transfer, a high incidence of refracture, pseudoarthrosis and difference in size between the donor fibula and the tibia which produces stress concentration during weight bearing (*1,4,7*). A recent study by Song *et al* (*18*) compared internal bone transport and use of vascularized fibular grafts for femoral defects and found internal bone transport to have better bone results and lesser limb length discrepancy than vascularized fibular grafts, which were associated with a high incidence of vascular failure. Technical expertise and facilities for microvascular surgery required for vascularized fibular grafts may also not be easily available in less developed countries.

Acute compression and subsequent distraction had been tried only for smaller defects (< 6cm) in tibia and femur (*14*) because of fear of vessel kinking in large gaps. It was thought that the high complication rate in studies using bone transport for tibial bone defects was because of a delay in contact and compression at the docking site due to the gradual closure of defect, which is not so in case acute docking is done. In a recent study by Magadum *et al* (*8*) with large tibial defects averaging 10 cm (highest 17 cm), it was found that acute compression and distraction was superior to internal bone transport. They did not report any neurovascular complication, axial deviation or need for bone grafting. Whether larger defects can be consistently treated by acute compression without complications is still debatable. We did not have any neurovascular complications in our study and axial deviation was seen in only 6 patients with large bone defects.

The treating surgeon faces the dilemma of offering limb salvage or amputation in large bone defects (*10*). While the cost of the acute care necessitated by the amputation are much lower, the projected costs of the prosthetic care for the remainder of the patients' life result in greater overall costs (*6, 21*). We believe that all such patients who have a sensate foot and are willing to participate in the long rehabilitation program should be offered limb salvage rather than amputation. All patients in our study opted for limb salvage.

Once docking has been achieved, several studies now recommend proceeding with early bone grafting to decrease the fixator time (*12,17*). As the leading edge of the intercalary fragment is avascular, which adds to a high possibility of soft tissue interposition, union can be delayed unless the sclerotic margins are trimmed and interposition removed (*12*). We performed bone grafting in 32% of our patients in which skin invagination was found at the docking site. To decrease the fixator time we performed trifocal osteosynthesis with two-level corticotomy in 3 patients where the defect size was > 12cm. The use of bone graft at the docking site ranges from 10% (*20*) to 50% (*10*) and 80-100% (*15,17*) in other studies. The authors advocate early bone grafting with freshening of fracture margins when docking is achieved.

The average external fixator time in our study was 8.8 months/cm and the mean external fixator index was 0.98 months/cm. It was less as compared to the study by Song *et al* (*18*) (20 patients, external fixator index 1.4 months/cm and external fixator time of 9.7 months) where the average defect was similar to our study (8.4 cm). It was also less than in studies by Paley *et al* (*11*) (external fixator index 1.7 months/cm and external fixator time 16 months) who reported on 19 patients with a mean bone defect of 10 cm, and Bobroff *et al* (*3*) (external fixator index 2 months/cm and external fixator time 16.7 months) with a mean bone defect of 9.45 cm.

The complication rate in our study was 2.88 complications per patient as compared to 1.5 complications per patient in a study by Paley *et al* (*11*). Another similar study in 12 patients by Bobroff *et al* (*3*) reported 3 complications per patient. The high rate of complications could be due to larger length of the transported segment, longer regenerate and associated soft tissue problems, wire cut-through, inadequate regenerate consolidation, and soft tissue interposition. Our patients needed an additional 2.4 procedures per patient for complications after the index surgery (frame application) which included fixator adjustments, wire exchange, abscess drainage, bone grafting or other specific actions, which was comparable to other studies (*3*).

Bone results in our study were better than functional results (52% excellent bone results versus 24% excellent functional results). This trend is consistent with other studies (*3,11*). The poor results (44% poor bone results and 24% poor functional results) could be attributed to the large defect size and associated high rate of complications and the fact that use of a relatively minor procedure of bone grafting at the docking site makes it a poor bone result (*6*) even if union is achieved.

CONCLUSION

Limb salvage in large bone defects should only be attempted in motivated individuals since a good outcome requires extensive patient cooperation and understanding. The treatment is long, difficult and fraught with complications that must be recognized and dealt with if success is to be achieved. The surgeon should set realistic goals both for himself and his patients while offering this method of treatment and one must not forget that an excellent bone result does not guarantee a good functional result, which depends on the condition of nerves, vessels, joints and bones (*3,10,11*).

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