Brief Communication

Ilizarov method with bone segment extension for treating large defects of the tibia caused by infected nonunion

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Infectious nonunion (INU) of the tibia is common after trauma, infection or repeated operations can lead to bone and soft tissue defects, long term nonunion, limb disuse, and amputation in severe cases. The incidence is increasing, and over half of cases occur after internal fixation. Open or closed bone grafts have been used to treat INU, but can be associated with severe operative wounds, poor overall efficacy, and complications such as nonunion and malunion.[1] In 1951, Gavriil Abramovich Ilizarov[1] devised an external fixation technique, which is now indispensable for treating open fractures, cases of delayed union, and nonunion and limb lengthening. It increases fracture stability and enables early weight-bearing. Recently, the use of the Ilizarov external fixation technique to treat INU has been investigated. This study aimed to investigate the efficacy of the Ilizarov technique in treating INU with bone extension.

Ethical approval for this study was obtained from the Institutional Review Board of Tianjin Medical University General Hospital, and written informed consent was obtained prior to their inclusion. The study was conducted in accordance with the guidelines of the Helsinki Declaration.

Twenty-one patients (15 male, 6 female; mean age 34.6 years, range 19-49 years) were recruited into this retrospective cohort study after attending in Tianjin Medical University General Hospital, Tianjin, China. Details were obtained from a review of the patients' medical records. Inclusion criteria of study were tibia large bone defects caused by infected nonunion. Exclusion criteria were tibia large bone defects caused by trauma, tibia large bone defects caused by non-infected nonunion and tibia infected nonunion without large bone defects. Patients underwent full physical examinations, with specific attention to the soft tissue blood supply, bone defect size and the stability of the fracture ends. X-rays were used to determine the location and type of fracture, the presence or absence of sequestrum and its size and location, and the size of the bone defect. Wound secretion samples were taken for culture and drug susceptibility tests, and appropriate antibiotics were administered for one week. Surgery was performed under lumbar epidural anesthesia. The aim of surgery was to debride the wound and to obtain free drainage. After the original fixation device and necrotic tissue was removed, the sequestrum was resected until the broken bone ends bled and the dead space was obliterated. In type A cases (chronic infection), soft tissue was used to cover the wound. In severe defects that could not be covered by this approach, the fracture was temporarily shortened to obtain adequate soft tissue. To avoid interference with the local vascular supply, shortening was usually less than 20% of the limb length. In cases of active infection (type B), dressings were changed, drainage inserted, and antibiotics given following debridement. When active infection was controlled, a segment of bone was obtained by osteotomy for extension. The site and extent of the bone defect was taken into consideration when the osteotomy site was chosen. Distal and proximal metaphyses were preferred, and the diaphysis was considered only when these sites were unavailable as it has a relatively poor blood supply. After surgery, the patients were given antibiotics for one week and began functional exercises. Extension using the Ilizarov external fixation device (Yian Lifang, Beijing, China) began 7 days postoperatively. In most cases, 4 to 6 extensions of 1 mm per day were required to extend the bone segment. X-rays were taken every 4 weeks to enable timely modifications to the extension and reshaping program. When the extended bone segment was in contact with the distal end of the fractured bone, its position and direction were adjusted and pressure was gradually exerted on the segment to stabilize the join. The fixation device was not removed until callus mineralization had occurred in the extended segment and bone union was achieved. Patients were completely weight-bearing for 2-4 weeks before the fixation was removed. On the day of removal, the patient attempted to walk with a loosened fixator to assess the reliability of the bone union. Clinical fracture healing was determined by follow-up x-ray examinations postoperatively, and complications were recorded. The fracture union was evaluated using Paley's fracture union score criteria as follows: excellent, fracture union without recurrent infection, local deformity $<7^0$ and leg length discrepancy <2.5 cm; good, fracture union with one or 2 of the 3 conditions above; poor, disunion of the fracture or re-fracture, or all 3 of the above conditions. Fractures affected the proximal tibia in five cases, the middle tibia in eleven and the distal tibia in 5. Infectious nonunion followed open fracture with steel plates in 8 cases, open fracture with bone nails in 6 cases, open fracture with external fixation in 4 cases, and closed fracture that was fixed internally with steel plates

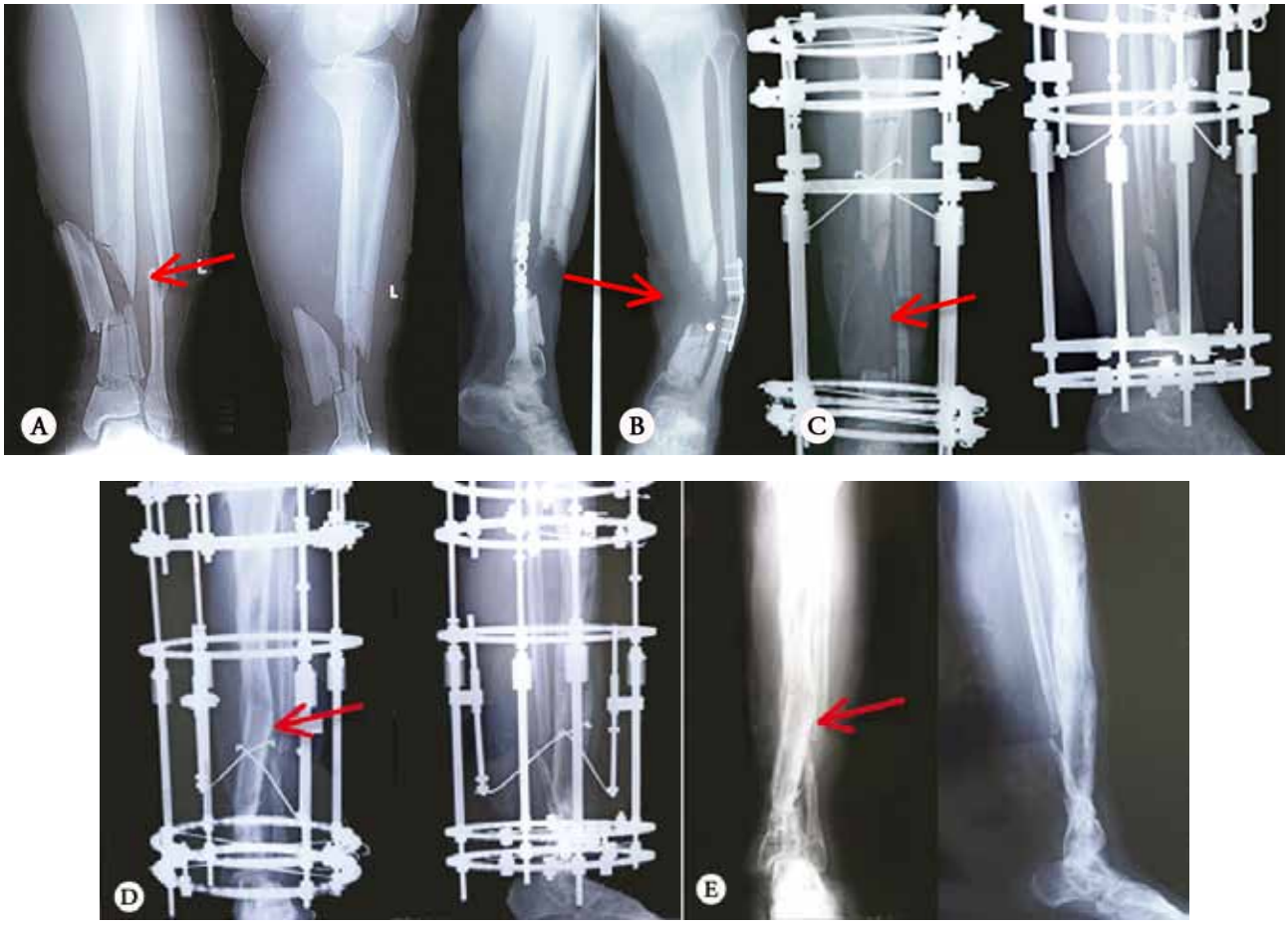

Figure 1 - Serial radiographs illustrating the Ilizarov method using bone segment extension for the treatment of infected nonunion of the tibia with a large bone defect (12 cm) in a 23-year-old man. Anteroposterior radiograph of the **A**) tibial open fracture, **B**) fracture after 14 operations. There was a bone defect and infection. **C**) Bone extension by the Ilizarov method following debridement. **D**) Bone healing after 12 months. **E**) Tibia after removal of the external fixation.

in 2 cases. The mean duration between the original injury and INU treatment was 8.6 months (range, 6-24 months), during which the patients underwent an average of 6 operations (range, 3-14). There were no major co-morbidities. According to the bone defect and infection classification proposed by Jain and Sinha,[2] 7 cases were type A2 (chronic infection, fracture gap >4 cm after debridement), 3 cases were type B1 (active infection, fracture gap <4 cm after debridement) and 11 cases were type B2 (active infection, fracture gap >4 cm after debridement). Sinuses had formed in 6 cases and bone was exposed in 15 cases; the largest area of exposed bone was approximately 7×5 cm and the smallest was approximately 2×1 cm. The average length of bone defects post-debridement was 6.6 cm (range, 3-12 cm). Patients were hospitalized for 1-5 months (mean, 1.7 months). All 21 patients were followed-up for 12-72 months (mean, 31 months). Stable fracture union was achieved in all patients. The time taken for fracture union was 6-12 months (mean, 7.8 months) and external fixation was in place for 8-14 months (mean, 9.8 months). According to Paley's fracture union score criteria, 19 cases were rated as excellent and 2 cases were good. A typical case is illustrated in **Figure 1**. Complications included superficial pinhole infection (n=3), which were cured by local care, weight reduction and oral antibiotics, skin allergy (n=1) treated with oral antihistamine drugs, malunion (n=2) that was managed with a second osteotomy and reshaping, early mineralization (n=1), where satisfactory union was achieved after a second osteotomy, and needle breakage (n=1) which required re-pinning and further fixation. There were no cases of deep infection, nonunion or dysfunction of the knee joint. Infectious nonunion is defined as a fracture that has not achieved union 6-8 months after injury with persistent local infection. The

infection produces a micro-environment that inhibits bone regeneration, reduces the stability of internal fixation, and significantly delays or inhibits fracture union.[3] With the recent proliferation of the use of internal fixation, INU following internal fixation now comprises more than 50% of cases. Infectious nonunion is associated with cutaneous deficiency, osteoporosis, joint stiffness, leg length discrepancy, and infection with drug-resistant bacteria, which makes management strategies difficult.[4]

The goal of the treatment of tibial INU is to restore the lines of force and achieve fracture union with a painless and functional limb.[5] The Ilizarov extension technique is suitable for bone defects of any length, causes minimal trauma and stable fixation and enables early activity and easy monitoring. However, a re-fracture can occur if healing is prolonged, the quality of the union is poor or bone remodeling is slow. To promote bone union, the bone ends can be debrided as necessary. Three patients in the current series required this due to trapped scarred skin at the fracture ends or an insufficient contact area for union.

The steel in Ilizarov fixators can become fatigued during use, leading to needle breakage during the later phases of bone extension and mineralization. This occurred once in this series, but as the callus was in the late mineralization phase, there was no need to change the needle. Early mineralization of the extended bone segment occurs with an incomplete osteotomy or inadequate distraction stress during the early extension phase. This should be considered when large changes are observed in the length of the extended segment and the distance between the fractured bone ends. One case in this study required a second osteotomy 2 weeks after the extension began, with a favorable outcome after a repeat osteotomy. Malunion of the extended segment is usually caused by the failure to correct the residual deformity during the later extension phases. Two patients missed a scheduled follow-up appointment and developed a malunion. Consequent lateral angulation was corrected by a second osteotomy.

This study has certain limitations, most importantly as it was a retrospective study with the chance of recall bias. The number of patients in this series was also relatively small, and future prospective randomized controlled studies will be required to confirm the conclusions of this current investigation.

In summary, bony union after INU can be achieved after local infection is controlled, free drainage is obtained, necrotic tissue has been removed, and a stable bio-mechanical and biological environment has been created. The Ilizarov technique for bone segment extension is simple, causes few complications, enables early functional exercise, promotes knee and ankle joint recovery, and reduces fracture-associated co-morbidities. With a skilled surgeon, careful postoperative management and prompt exercise program, this is an effective treatment for tibial INU.

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