

Case Report

Ilizarov bone transport combined with antibiotic cement spacer for infected tibial nonunion

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Abstract: Purpose: To evaluate the curative effect of Ilizarov bone transport combined with antibiotic cement spacer for infected tibial nonunion with bone defect. Methods: We retrospectively reviewed the outcomes of 58 patients with infected tibial nonunion from January 2008 to March 2011 at our institution. Patients were treated with complete debridement, radical sequestrectomy, antibiotic cement spacer implantation, bone transport using the Ilizarov external fixator, and soft tissue reconstruction. Clinical efficacy was assessed using Paley's grading system and patient satisfaction at the last follow-up. Results: Follow-up ranged from 24 to 63 months (average, 31.6 months). Mean size of the tibial defect was 9.2 cm (range, 6-15 cm). The soft tissue defect was closed successfully in all cases. Patients eventually achieved union with a mean bone union index of 1.2 months/cm at an average of 10.6 months (range, 8-31 months). In terms of Paley grade, 30 patients had excellent results, 23 good, and 5 fair. Functional results were excellent in 28 patients, good in 18, and fair in 12. Thirty-five patients felt extremely satisfied, 18 satisfied, and 5 acceptable with the functional outcome. Complications included pin site infection in 18 cases, limb length discrepancy less than 1.5 cm in 10, knee stiffness in 5, equinus deformity in 4, infectious recurrence in 1 and pin breakage in 1. There was no refracture at the reconstruction site. Conclusion: Ilizarov bone transport combined with antibiotic cement spacer is a versatile and effective method for treatment of infected tibial nonunion.

Keywords: Ilizarov bone transport, bone defect, infected tibia nonunion, antibiotic cement

Introduction

Infected tibial nonunion with accompanying bone and tissue defects, limb deformity, joint stiffness, and disuse osteoporosis-usually resulting from high-energy injury or as a complication of open reduction and internal fixation-still presents a great challenge for orthopedic surgeons. Adaptive treatment possibilities include application of antibiotics, complete bone and soft tissue debridement, and reconstruction of bone and soft tissue defects. Few methods have been confirmed to be effective for tibial nonunion with defect, such as autologous corticocancellous bone graft or vascularized fibular graft. However, corticocancellous bone graft is adapted for defects less than 4 cm [1-3]. For patients with large segmental tibial defect, the complication rate when treated with massive cancellous bone graft is much higher than that when treated with Ilizarov bone transport; Ilizarov bone defect reconstruction is faster, safer, less expensive, and considered an

adjunct surgical procedure [4]. Vascularized fibular graft can be extremely difficult to apply. In addition, mismatch between tibial and fibular cross-sectional areas may result in a high rate of refracture. These factors limit application of vascularized fibular graft in the clinic. Ilizarov bone transport is a versatile method that can provide a large diameter of bone with intact blood supply to fill the bone defect. It is also highly recommended for the management of tibial nonunion, especially nonunion with bone loss [5]. Moreover, this method has the ability to correct coinciding deformity, shortening, soft tissue loss, and nearby joint contractures [6, 7]. For patients with infected nonunion, the sequestrum must be resected using an en bloc method, which results in large segmental bone loss. However, this complex is recommended to be resolved by Ilizarov distraction osteogenesis [7-9].

Radical debridement is the most important step to eradicate infection of bone and soft tis-

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Figure 1. A 46-year-old patient experienced 1 year proximal infected tibial nonunion with equinus deformity after open reduction and internal fixation for the tibial fracture in local hospital. Sinus was present at the anterior leg, and the fracture was nonunion because of persistent infection (A); MRI was accomplished in order to determine the extent of the infection (B); thorough debridement of the infected soft tissue and bone combined with implant of antibiotics cement spacer and distal tibial bone transport was carried out (C); the equinus deformity was corrected by extension of frame to the foot (D); eleven months later, the external fixators was removed, and excellent union was obtained at the docking site and the lengthening region (E).

sue, but antibiotic cement is also necessary for eliminating infection. Currently, antibiotic cement is widely applied for chronic osteomyelitis and postoperative infection after arthroplasty. In addition, antibiotic cement can be used as a spacer in the bone loss zone which can form a soft tissue tunnel for bone transport [10, 11].

In this study, we retrospectively reviewed a series of patients with infected tibial nonunion who were treated successfully with Ilizarov bone transport combined with antibiotic cement spacer.

Materials and methods

Patients

We retrospectively researched a cohort of 58 patients with infected tibial nonunion at our institution who were treated with Ilizarov bone

transport and antibiotic cement spacer from January 2008 to March 2011. There were 38 men and 20 women with a mean age of 29.4 years (range, 18-51 years). In the primary injury, 41 fractures were open and 17 were closed. According to AO classification, 18 fractures were type A, 31 were type B, and 9 were type C. The cause of initial trauma was fall from a height in 7 patients, traffic accident in 39, and heavy weight injury in 12. The mean time from initial treatment was 30.5 months (range, 6-50 months). The mean of operations before this treatment was 6.3 (range, 3-10). All patients had soft tissue defect, bone exposure, sinus formation, or bone paste scar formation to a different extent. Concomitant deformities included equinovarus in 18 patients, contracture of the Achilles tendon in 10, malalignment in 8, and hammer toe in 7. Patients were classified in terms of the classification system reported by Jain and Sinha [3]; there were 27 cases with

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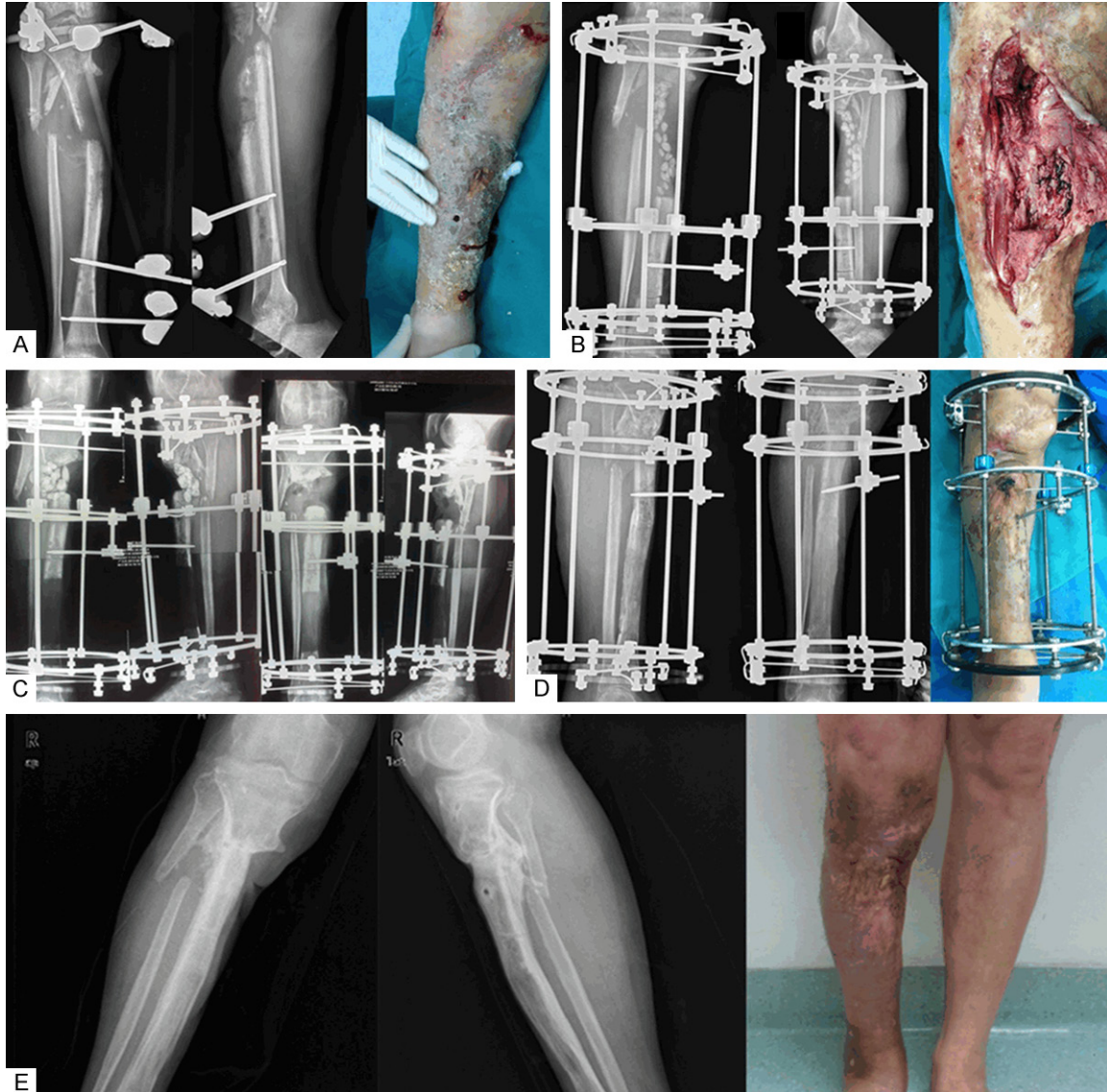


Figure 2. A 38-year-old patient, undergone several times of debridement and flap transfer after open and comminuted fracture of right tibia due to vehicle accident, still presented infection nonunion with bone loss (A); removal of the external fixator, thorough debridement of the infected soft tissue and bone which led to 15 cm bone and large soft tissue defect, treatment with implant of the antibiotic cement spacer and distal tibial bone transport was fulfilled at our hospital (B); as the transported bone segment arrived toward its destination, the bead-like antibiotic cement were crimped together, which were then gradually removed out to leave space for the bone transport (C); eighteen months later, bone transport and docking site were union with excellent soft tissue recovery (D, E).

quiescent infection and 31 with active infection. In cases with active infection, 15 patients had resistant *Staphylococcus aureus*, 8 had *Pseudomonas aeruginosa*, and 8 had mixed infection.

Treatment

Preoperative examination included radiography and sometimes magnetic resonance imaging of the leg (Figure 1), white blood cell count, C-reactive protein level, and erythrocyte sedi-

mentation rate. Whether diabetes mellitus or peripheral vascular disease existed also was confirmed, since some internal diseases, such as anemia, hypoproteinemia, and diabetes mellitus, must be treated before surgery. According to physical and imaging examinations, extent of soft tissue and bone debridement was preliminarily determined preoperatively. In addition, size, number, and laying position of Ilizarov external fixator parts also were confirmed before surgery. Systemic sensitive antibiotics

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were applied based on positive culture outcome of deep wound drainage.

All patients were operated on under general anesthesia, without use of a tourniquet, so as to differentiate viable soft tissue and bone, and attain complete debridement which was continued until punctate bleeding. During sequester resection, distal and proximal portions of infected bone were cut by an osteotome; sometimes the ends should be drilled to confirm whether thorough debridement was attained. Soft tissue and sequester were sent for cultures. There were 17 patients with residual internal hardware, including 7 with plates and screws, 10 with intramedullary nail, all of which were removed. Then, the Ilizarov circular combined-type external fixator (Beijing Institute of External Skeletal Fixation Technology, China) was applied with equal space between the leg and the ring of the fixator and correct alignment. Segmental bone defects were filled with columnar or bead-like antibiotic-impregnated cement (Depuy, US) mixed with tobramycin and vancomycin-ten grams of cement mixed with 1.2 g tobramycin and 0.5 g vancomycin. Soft tissue defects may be covered by negative-pressure materials or reduced by shortening the extremity by 3-4 cm and recovering limb length secondarily. Subsequently, through a separate mini-incision, corticotomy of the tibia was performed at the distal or proximal tibial metaphysis, depending on the bone defect site, for bone transport. For patients with concomitant equinovarus, the concomitant management divided into two types: a) muscle strength of ankle dorsiflexion existed, only maintained with extension of frame to the foot at the same time b) without muscle strength of ankle dorsiflexion, achilles tendon lengthening was applied and maintained with extension of frame to the foot.

Postoperatively, systemic antibiogram-specific antibiotics were continued for approximately 6 to 8 weeks according to intraoperative cultures and sensitivity. Bone transport was initiated on the tenth postoperative day, and proceeded at a rate of 1 mm per day, which was divided into 4 times of 0.25 mm each. Concomitant equinovarus or malalignment also was corrected via the Ilizarov external fixator. In the process of bone transport, dressing was changed regularly to promote granulation growth, which was fol-

lowed by skin grafting. For broad wounds in which granulation failed to grow adequately, skin traction was performed to reduce the wound during the process of bone transport. During hospitalization, patients were trained to protect and distract the Ilizarov external fixator. On the second day after surgery, physical therapy was started included progressively partial weight bearing with crutches, knee and ankle range of movement exercises, and isometric and isotonic muscle strengthening exercises.

Follow-up and evaluation

Patients were examined monthly using radiography to monitor callus growth in the distraction areas and alignment of the transport segment. The antibiotic cement was gradually got out when the ends of the transport segment contacted it (**Figure 2**). When the bone segment reached the former nonunion site, which was named the "docking site", the last segment of antibiotic cement spacer was removed. Then, refreshing of bone and autogenous cancellous bone grafting were carried out. Concomitantly, 20 ml marrow obtained from cancellous donor site of iliac bone was injected to the medullary cavity of the distraction gap. If minimal leg-length discrepancy existed after bone transport, the frame was lengthened at the time of grafting of the docking site. External fixator were not removed until consolidation of the distraction area and union of the docking site were achieved. Clinical and functional outcomes were evaluated using Paley's grading system [12].

Results

After a mean follow-up of 31.6 months (range, 24-63 months), all 58 patients experienced successful healing with bone union at both corticotomy and tibial docking sites, as well as favorable soft tissue wound coverage, with no limb-length discrepancy exceeding 2 cm. Finally all the patients can walk without the help of crutches or orthoses. Mean bone transport length was 9.2 cm (range, 6-15 cm) and mean bone union index was 1.2 months/cm. Frames were removed after a mean of 10.6 months (range, 8-31 months). 12 patients with preoperative equinovarus and 8 patients with preoperative malalignment achieved successful correction simultaneously, and 6 preoperatively equinovarus failed to be corrected completely.

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According to Paley grade at the final follow-up, 30 patients had excellent results, 23 good, and 5 fair. Functional results were excellent in 28 patients, good in 18, and fair in 12. Thirty-five patients felt extremely satisfied, 18 satisfied, and 5 acceptable with the functional outcome.

Eighteen patients (31%) experienced superficial infection around the pin sites, which was cured by local treatment and oral antibiotics. Ten patients had limb length discrepancy less than 1.5 cm. Five patients with knee joint stiffness recovered normal range of motion after functional exercises. Four patients developed equinovarus deformity in the process were treated by Achilles tendon lengthening after frame removal. One patient experienced pin breakage, which was treated by changing the pin. One patient who combined with diabetes mellitus experienced subcutaneous abscess at the docking sites, and was finally cured by several debridement.

Discussion

Treatment of infected tibial nonunion presents significant challenge for orthopedic surgeons despite major advancements in fixation, soft tissue management, and antibiotic therapy. Management includes thorough debridement, stabilization of the fracture, and reconstruction of the bone defect. Radical debridement including necrotic soft tissue and sequestrum usually results in bone and soft tissue defects, which increase the complexity of the subsequent reconstruction. Several methods can be adopted for the bone defect, such as corticocancellous bone graft, vascularized autogenous bone graft, and Ilizarov bone transport. Corticocancellous bone graft is ideal for patients with a small defect. Vascularized autogenous bone graft, usually vascularized fibular graft, is associated with a high rate of refracture, donor site morbidity, and complexity of the operation [3]. Moreover, the bone and functional results of vascularized fibular grafting compromise those of bone transport [13]. Ilizarov bone transport, an effective and minimally invasive method, has been advocated for management of infected tibial nonunion with bone loss in many studies [5-7, 9-11, 14]. This method utilizes an Ilizarov external frame that can provide stability, correct deformities and malalignment [15], and stimulate soft tissue regeneration

simultaneously [16]. In addition, since the Ilizarov frame can provide stability, physical exercise can be carried out early postoperatively, improving the function of nearby joints and avoiding disuse osteoporosis. In this research, the bone defect after debridement was larger than 4 cm after debridement, with most patients also having soft tissue defects; thus Ilizarov bone transport was the optimal treatment method.

Eradication of infection is the primary goal of this treatment. Despite radical excision of necrotic soft tissue and dead bone, there still remains a risk of infection recurrence [17]. Antibiotic-impregnated cement, which has been widely used for bone and joint infections, increases the antibiotic concentration at the infection site to approximately 200 times higher than that with systemic administration, and also inhibits bacterial growth, providing a relatively germ-free environment [3, 18-20]. Furthermore, the elution of antibiotic-impregnated cement continues for more than 6 months, and has been found to be safe [18]. Besides release of antibiotics at the infection site, the antibiotic-impregnated cement spacer fills dead space and provides mechanical support, which prevents fibrous tissue growth into the bone defect space and creates a soft tissue tunnel for bone transport. Moreover, the antibiotic-impregnated cement spacer has a biologic function by creating a pseudosynovial membrane, promoting angiogenesis by producing vascular endothelial growth factor, regulating bone metabolism by producing transforming growth factor β 1, and inducing formation by secreting bone morphogenetic protein [21]. In this research, bone defects were filled with antibiotic-impregnated cement. In the early stage, with the bone segment moving, columnar or bead-like antibiotic-impregnated cement were gradually removed through a small skin incision during internal bone transport, which avoided soft tissue growth into the defect space and created space for bone transport. In addition, the sustained release of antibiotics can radically eradicate residual germs. The low rate of infection recurrence in this study can be partly attributed to the use of antibiotic-impregnated cement.

Bone transfer creates a docking site when the segment arrives at its destination. There is usually fibrous tissue interposed at the docking

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site, which affects union [22, 23]. Spontaneous union at the docking site is unusual, but possible. There are strategies for promoting union at the docking site, such as increased compression, the accordion technique, osteotomy of the docking ends, removal of interpositioned tissue, and bone grafting [22]. Many studies have adopted these former methods, but the rate of delayed union or nonunion at the docking site may reach 74% [10]. Although most patients can achieve docking site union with the above methods, they can be time consuming and increase the duration of external fixation and patient discomfort. Some studies have demonstrated that revision and bone grafting of the docking site can advance union and decrease the mean time of fixation [6, 13, 22]. Lovisetti et al. [24] compared union at the docking site using closed versus open strategies, and found that index lengthening with a closed strategy was 2.04 months/cm, while that with an open strategy was 1.73 month/cm. Because union of the docking site was the rate limiting step in bone transport treatment, we adopted open revision and bone grafting for the docking site, which decreased the external frame time. In addition, the mean bone union index in this research was 1.2 month/cm, which is lower than that of some studies using a closed strategy. As the percutaneous grafting bone marrow injection had been conformed to be a safe and effective treatment for delayed or nonunion [25-27], autologous bone marrow injection to the medullary cavity of the distraction gap, which we thought can increase the amount of osteoprogenitor cells in the distraction gap to advance the consolidation of the distraction gap, may be another factor to promote the union of docking site and distraction gap.

Tibial nonunion is usually combined with a soft tissue defect, and soft tissue reconstruction presents an important step in management. Several methods, including negative-pressure wound dressing and skin grafting [8], flap coverage [10], and skin traction [16], can be adopted to close the wound. However, flap coverage is associated with flap necrosis and donor site morbidity. In this study, for patients with a broad soft tissue defect, after the antibiotic-impregnated cement spacer was placed in the bone defect site, negative-pressure wound dressing, which is helpful for granulation tissue growth, was applied to cover the wound and the

spacer. Gradually, granulation may cover the spacer, which can be followed by skin grafting to cover the wound. For patients with inadequate granulation growth, skin traction can be used to reconstruct the wound during the process of bone transport, as described by Rozbruch et al. [16]. Finally, all wounds were reconstructed and it demonstrates the effectiveness of this method.

In our study, preoperative concomitant deformities, including equinovarus in 12 patients and malalignment in 8 patients, were corrected simultaneously, which is one advantage of Ilizarov bone transport. Schottel et al. [28] added an additional foot ring to prevent equinus contracture or hinges between the foot and distal tibial rings for gradual equinus correction. Sala et al. [29] also corrected equinus ankle contracture using the Ilizarov frame during the process of bone transport.

All patients in this study underwent radical debridement, soft tissue reconstruction, bone transport, and bone grafting at the docking site. After a mean follow-up of 31.6 months, all patients experienced successful healing with bone union at both corticotomy and tibial docking sites, as well as favorable soft tissue wound coverage, with low infection recurrence rate. Mean bone transport length was 9.2 cm, mean bone union index was 1.2 month/cm, and average external frame time was 10.6 months. A total of 51.7% of patients had excellent bone results, 39.6% good, and 8.6% fair. Functional results were excellent in 48% of patients, good in 31.0%, and fair in 20.7%. Bumbasirevic et al. [9] treated 30 cases of infected tibial nonunion with bone transport using the Ilizarov method, and reported that 97% of patients achieved bone union, with a mean maturation index of 1.04 and mean frame index of 1.48 months/cm, which is similar to the results of this study. Song et al. [13] managed 20 patients with internal bone transport and antibiotic-loaded cement beads; the mean defect was 8.4 cm and the mean external frame time was 9.7 months. However, the functional outcomes of our study are slightly poorer than those of the above studies. The reason maybe the longer intervals from initial injury to surgery in our study, which may have influenced function.

All complications in this study-pin site infection, joint stiffness, equinovarus deformity, and pin

breakage-were managed by proper methods, which included local treatment and oral antibiotics, physical exercise, tendon lengthening, and changing the pin. Fortunately, there was no limb-length discrepancy exceeding 2 cm or refracture in this series. Although Ilizarov bone transport has several disadvantages, such as a cumbersome external frame, long-term treatment, and high rate of complications, it is still an excellent method for treating complicated infected tibial nonunion.

In conclusion, ilizarov bone transport combined with antibiotic cement spacer, which can reconstruct the bone and avoid infection recurrence, is a safe and effective method for treating infected tibial nonunion. Despite the associated complications, a detailed preoperative plan, regular follow-up, and timely management of complications can help achieve a satisfactory outcome.

Disclosure of conflict of interest

None.

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