*Acta Orthop. Belg.*, 2016, **82**, 599-609

*ORIGINAL STUDY*

# Is acute compression and distraction superior to segmental bone transport techniques in chronic tibial osteomyelitis ? Comparison of Distraction Osteogenesis Techniques

Levent Eralp, Halil İbrahim Balci, Mehmet Kocaoglu, Cengiz Sen, Mustafa Celiktas, Yılmaz Tomak, Mahir Gülşen, Goksel Dikmen

**Treatment of tibial osteomyelitis with infected, necrotic, unstable bone segments (Cierny-Mader Type IV local osteomyelitis) includes débridement and segmental resection, which results in long bone defects. Reconstruction may be with distraction osteogenesis. Segmental bone transport and acute compression and distraction techniques are two main distraction osteogenesis techniques used in the treatment of Type IV local tibial osteomyelitis.**

**In this retrospective, four-center study we compared these two techniques during a 15-year period. 29 patients treated using segmental bone transport technique and 45 patients were treated using acute compression and distraction technique. The mean age (p= 0,34) and the mean bone loss with preoperative shortening (P=0,08) and the mean number of previous operation (p=0,06) were not different in these two groups. . At latest followup, functional and radiographic results were evaluated**

**There was no difference between two technique on the Paley's scoring system ( p=0,33) and in the total number of complication(p=0,16). Mean external fixator index was lower in the second group ( p=0.02 ).**

**Both techniques can be used safely; however, the acute compression distraction technique may provide greater patient satisfaction because of shorter external fixator index, although future studies will be needed to determine whether this is.**

**Keywords** : tibia osteomyelitis ; distraction osteogenesis

*Each author certifies that he or she, or a member of his or her immediate family, has no funding or commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.*

*Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.*

■ Levent Eralp MD[1],
■ Halil İbrahim Balcı MD[1],
■ Mehmet Kocaoglu MD[2],
■ Cengiz Sen MD[1],
■ Mustafa Celiktas MD[3],
■ Yılmaz Tomak MD[4],
■ Mahir Gülşen MD[5],
■ Goksel Dikmen MD[6]

[1]*Department of Orthopaedics and Traumatology, Istanbul University Istanbul Medical Faculty, Turkey*
[2]*Department of Orthopaedics and Traumatology, Istanbul Memorial Hospital, Istanbul, Turkey*
[3]*Department of Orthopaedics and Traumatology, Ortopedia Hospital, Adana, Turkey*
[4]*Department of Orthopaedics and Traumatology, On Dokuz mayıs University, Samsun, Turkey*
[5]*Department of Orthopaedics and Traumatology, Ortopedia Hospital, Adana, Turkey*
[6]*Department of Orthopaedics and Traumatology, Acıbadem Maslak Hospital department of orthopaedics and traumatology, Turkey*

Correspondence: Halil İbrahim Balcı MD Department of Orthopaedics and Traumatology, Istanbul University Istanbul Medical Faculty, Capa 34690 Istanbul, Turkey email: balcihalili@hotmail.com

## INTRODUCTION

The treatment strategy for chronic osteomyelitis has changed to a great extent over the past 20 years because of better staging systems, advanced surgical techniques, antibiotic regimens, and adjuvant treatment modalities (4). Cierny et al. (5) classified chronic osteomyelitis into four anatomic types and further staged the pathology according to the extent of local and systemic compromise in patients. Treatment of tibial Cierny-Mader Type IV osteomyelitis, which is characterized by an infected, necrotic, and unstable bone segment, is suggested as to be treated using segmental resection that results in a long bone defect (5). There are many alternative treatment options for bone defects that occur after bone segment resection due to chronic osteomyelitis; eg, bone grafting, Papineau method, free muscle flaps, vascularized bone grafts, reconstruction by intramedullary nailing, or plate osteosynthesis, and grafting (1). Although bone healing can be obtained using these treatment options, the treatment time is usually very long, and microsurgical interventions are often required. Moreover, these techniques also fall short in terms of alignment and limb length equality. Additionally, if the treatment is unsuccessful, morbidity increases significantly and possible future treatment becomes more demanding (1). Ilizarov's principles enable the treatment of osteomyelitis and associated problems, such as shortening, deformity, and joint contractures (2,3,6,7,8,9,10,13,14,15,16,17,19,21). After resection, local and systemic antibiotic treatment is followed by transportation of the healthy portion of the bone to the defect area. Alternatively, acute compression of the defect area and lengthening from a healthy part of the bone can be performed. Both are important classic distraction osteogenesis techniques used for Type IV osteomyelitis (3, 8–10, 14, 17,19,21).

The segmental transport technique requires two-staged treatment protocols. After the resection of the infected segment, antibiotic-impregnated bone cement spacers, in the form of beads or rods, are used both to fill the gap and to release local culture-specific, heat-stable antibiotic. In the second stage, a healthy segment is transported by a metaphyseal osteotomy with new bone formation at the nonaffected area of the bone. The acute compression and distraction technique involves closing the gap produced after the resection acutely and/or gradually and lengthening the bone through another osteotomy on the healthy side of the bone (19, 20). The acute compression and distraction technique, a one-stage treatment for the tibial defect, is reportedly associated with a shorter treatment period, fewer soft tissue applications, and lower complication rates than the segment transport technique, which also has problems related to the transported segment and docking side (20). Saleh et al compared these two techniques (19). Their study cohort consisted of both tibia and femur cases with differing diagnoses that included trauma, nonunion, deformity, and infection. However, to our knowledge, there have been no comparisons of these two techniques for the reconstruction of bone defects resulting from chronic tibial osteomyelitis.

We compared the advantages and disadvantages of acute compression and distraction over the segment transport technique in the treatment of Cierny-Mader Type IV chronic tibial osteomyelitis in a multicenter (four centers) retrospective study. We specifically sought to compare them with respect to a bone and functional scoring system described by Paley et al, the external fixator index, and complications.

## PATİENTS AND METHODS

### Study Cohorts

In this retrospective, multi-center study (four centers), over a 15-year-period, 32 patients were treated using segmental bone transport technique (group 1) and 49 patients were treated using acute compression and distraction technique (group 2). In group 1, 29 patients (90%) were followed up for a mean of 63 months (range, 36 to 85 months), and in group 2, 45 patients (92%) were followed up for a mean of 55.6 months (range, 12-66 months). The main reason for the lost in follow up was the lack of the last visit of patients for the research. Acute shortening offers advantages over segment transport in patients who present with no vascular insufficiency with soft-tissue defect of 3 to 5 cm. By the way it is possible to avoid free flap to cover the wound (22). Patients who underwent combined techniques for segment reconstruction were not included in the study (12). Between 1997 and 2012, 29 patients (20 males, 9 females) with a mean age of 37.6 years (range, 11–61 years;) underwent segment transport reconstruction surgery, and 45 patients (38 males, 7 females) with mean age of 34.8 years (range 10-62 years ), underwent acut shortening and lengthening technique. The mean bone loss was 5.3 cm in the group 1 and 5.9 cm in the group 2. Additional soft tissue reconstruction procedures included rotational gastrocnemius flap in 3 patients, cross-leg flap in 1 patient, free latissimus dorsi flap in one patient in group 1, and one free latissimus dorsi flap in group 2. A second docking site grafting, was used in 18 patients in group 1 because of lack of union. Eight patients in group 2 also needed docking site grafting. In group 2 docking site grafting is used for the two stage treatment. There were no differences in demographics and clinical variables between the two groups (Table I). The mean follow-up was not statistically different between two groups, 63 months (range, 36–85 months) in group 1 and 55.6 months (range, 12–66) in group 2 (p=0.18).

Informed consent was obtained from all patients and the institutional review board approved the study.

## Resection

The area of resection was determined through preoperative planning that includes radiographs and T2-weighted magnetic resonance imaging (MRI). MRI is especially used to detect any skip abcesses with in the long bone distant to the bone defect site. After the removal of hard ware, we resected dead bone until we reached cortical bleeding, the so-called paprika sign. Infected scarred soft tissue was debrided and tissue cultures were taken to ascertain the appropriate antibiotic treatment in the postoperative period.

The dead space was filled with custom-made antibiotic-impregnated polymethylmethacrylate in group 1, (2.4 g teicoplanin and 40 g polymethylmethacrylate powder in bead or rod form). We applied the intramedullary rods and custom-made braces or external fixation for temporary fixation of limbs, especially to patients with severe local sepsis, as defined by laboratory parameters or culture with mixed microorganisms. Temporary external fixation and antibiotic-impregnated cement were used in 18 patients in group 1 and in 8 patients in group 2 in whom there were high acute phase reactant values and active fistula where the osteomyelitis was very aggressive.

## Segmental Bone Transport

Antibiotics specific to the microorganisms in the culture-antibiogram results were used for 6 weeks (3 weeks intravenously and then 3 weeks by mouth). At the end of this period, if the levels of C-reactive protein and erythrocyte sedimentation rate had returned to normal, the reconstruction surgery was performed. The frame consisted of four rings connected with rods as in the classic Ilizarov frame, beacause it must allow sliding for segment transport either internally or externally. It also may be achieved with spatial fixators (Fig. 1,2,3,4,)

Internal segment transport was selected in seven patients whose defects were larger than 8 cm (mean, 11.1 cm). If internal transport was used, one of the rings was used as a “dummy” ring (no connection to the bone) for further compression of the docking

Table I. — Demographic data of the two groups (*Analyzed by Mann-Whitney U test)

| Variable | Segmental bone transport group (N:29) | Acute shortening and lengthening group (N:45) | P value* |
|---|---|---|---|
| Mean age (years) | 37.6 (Range 15-61) | 34.8 (Range17-62) | P=0,34 |
| Mean number of previous operations | 2.11 (Range 1-12) | 2.52 (Range1-10) | P=0,06 |
| Mean bone loss with preoperative shortening (cm) | 5.3 (Range 1-17) | 5.9 (range 1-12) | P=0.08 |

*Fig. 1.* — Segment transport with spatial type circular external fixator

*Fig. 2.* — Docking of the segment at distal and consolidation of the proximal part

*Fig. 3.* — Radiologic view of the tibiaafter the end of treatment

*Fig. 4.* — Clinical view of the patient after the end of treatment. Free flep application to cover the the bone at first stage of treatment is seen

site. For external transport, all rings were fixed to the bone with K-wires and Schanz pins (14).

### Acut shortening and lengthening technique

Eigth patients in the group 2 were implanted with beads impregnated with antibiotic (1600 mg teicoplanin and 160 mg tobramycin) after resection to fill the dead space with temporary external fixation and proper antibiotic regimens. Antibiotics were given for 6 weeks due to the severity of the infection, as the first session of the treatment. The other 37 patients were treated in one session. Before the acute shortening, an intramedullary Steinmann pin was used temporarily to secure alignment. Reference K-wires were inserted proximally and distally to assist the rotation, and once the alignment was confirmed via AP and lateral views on an image intensifier, the external fixator of four rings was fixed to the reference wires. At this point, acute shortening was performed. If the distal arterial circulation was maintained, which was confirmed using Doppler ultrasound and pulse oximeter, the operation could proceed. Hand-held vascular doppler ultrasound was used with most of the patients to evaluate distal (dorsalis pedis and posterior tibial arteries) arteries at the foot and ankle. In the absence of a distal arterial pulse, sometimes because of hypotensive anesthesia, we checked the circulation with pulse oxymeter to monitor the pulse at the extremities. Shortening had to be distracted to the point at which the pulse and circulation returned to normal, whereupon the remaining shortening could be performed gradually by 2 to 3 mm/day. In our study, the mean acute shortening was 3.5 cm (range, 2–4 cm). If the distal fragment was shorter than 4 cm or the lengthening was planned at the distal tibia, then the frame was extended to the foot to increase stability. Furthermore, K-wires and hydroxyapatite-coated Schanz screws, were used for fixation to provide greater stability (20) (Fig.5,6).

### Postoperative Treatment

Knee and ankle ROM exercises were initiated as soon as postoperative rehabilitation. The ankle was held in neutral flexion by splinting during rest. Weight bearing was allowed with two crutches as tolerated.

The lengthening through the osteotomy site was started at 4 x 0.25 mm per day on the seventh postoperative days in both groups. Distraction rate is decreased to 3*0,25 mmper day according to x ray controls. Patients were followed up in outpatient clinics every 2 weeks. After two-stage treatment, there was no need for further antibiotic therapy, but in one session treatment, especially in group2, parenteral and oral antibiotic therapy were prescribed according to culture results.

Once docking was achieved in group 1, the transported segment was fixed to the dummy ring with K-wires and Schanz pins for additional stability in a second operative session. After bony union, the fixator was removed, and a preventive brace was worn for at least 4 to 6 weeks. During this period, partial weight bearing was allowed with two crutches.

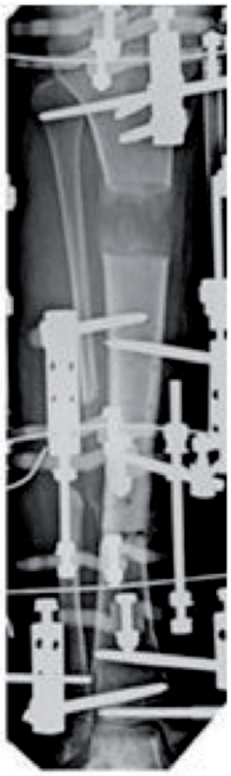

***Fig. 5.*** — Radiologic view of acut compression at distal part and distraction from the proximal osteotomy applied to reconstruct the defect occured after the debridement of the tibia osteomyelitis

***Fig. 6.*** — Radiological view of the patient after the end of treatment with non limb length discrepancy

### Outcomes and Statistical Analyses

Outcomes were evaluated by the senior author of the study by chart review, using the bone and functional scoring systems described by Paley et al. (16). The bone scoring system described by Paley et al considers bone union, regenerate quality, deformity, shortening and infection. The functional scoring system described by Paley et al considers return to daily activities, limping, and equinus deformity. Complications were classified as problems, obstacles, or sequelae according to Paley's system (14,16). External fixator index (EFI), and number of complications per patient were recorded. External fixator index is calculated by the numbers of days divided by the lengthening in cm. These parameters were likewise calculated based on a chart review.

Normality control was performed with the Shapiro-Wilk test and histogram graphics. Data are given as median, minimum, maximum, frequency and percentage. Paley's bone and functional scores are evaluated with Fisher 's exact test. The Mann-Whitney U test was used for statistical analysis to evaluate significant differences between groups in demographics, EFI and number of complications per patient. The significance threshold was p<0.05 and the analyses were two-way. Analyses were done using SPSS 21 software.

## RESULTS

There was no difference in Paley scores between the groups with the numbers available, either in terms of bone scores or functional scores (p=0.29 for functional and p=0.33 for bone score). In the group 1, bone scores were excellent in 21 patients, good in four, and poor in four. The functional scores were excellent in 22 patients, good in three, and poor in four(15). (Table II). In group 2, bone healing was obtained in all patients, including those who underwent bone grafting for delayed union. The bone scores were excellent in 35 patients, good in eight, and fair in two. The functional scores were excellent in 34 patients, good in eight, fair in two, and poor in one (Table III).

The external fixator index was higher (62.6 days/cm) in group 1 than in group 2 (48.4 days/cm) (p=0.01) (Table IV). The bone healing index was higher in group 1 (1,75 month/cm) than group 2 (1.35 months/cm) (p=0.02).

There were no differences between the groups in terms of the number of complications per patient (1.28 vs 1.31 in group 2 and group 1, respectively; p=0.16 (Table IV). Complications were categorized as problems, obstacles, and sequelae, as described as Paley et al (14). In group 1, there were 21 problems; these consisted of superficial pin-tract infection that did not result in premature pin removal in 17 patients, and limited range of motion of the ankle in four patients, resolved with intensive physiotherapy. Eighteen patients experienced obstacles, which were delayed union at docking sites; these underwent autogenous bone grafting. There were four sequelae: two patients exhibited nonunion at the end of treatment. Two patients refused the suggestion to correct the varus deformity owing to the plastic deformation at the distraction side after the removal of the external fixator. In group 2, a total of 16 problems were observed: pin-tract infections that did not result in premature pin removal occurred in six patients. Ten patients experienced delayed maturation at the distraction side. Eight patients exhibited delayed union as an obstacle at compression side and thus underwent autogenous bone grafting. Valgus deformity in two patients and 10° procurvatum deformity in one patient were observed as sequelae in this group.

## DISCUSSION

Treatment of tibial osteomyelitis with infected, necrotic, unstable bone segments (Cierny-Mader Type IVB local osteomyelitis) is a challenge because these patients generally have already had several previous surgical interventions. They often have soft tissue problems, and by definition, the bone is unstable. According to Cierny et al. (4,5,12), the only cure for osteomyelitis is radical debridement until viable, bleeding bone is obtained. Radical debridement, however, creates further bone defects requiring complex reconstruction techniques. Treatment modalities such as the Papineau method, bone grafting, nonvascular fibula grafting, and plate or intramedullary fixation provide bone healing, but shortening and deformity still remain unresolved (11), which interfere with activities of daily living. Cierny and Zorn (6) compared the results of segmental bone defects in the tibia with bone transport and massive autologous bone graft and found the results favored distraction osteogenesis. Distraction osteogenesis provides a good opportunity for reconstruction by replacing the defect with periosteal new bone formation and increasing blood flow at the area, which offers great advantages, elimination of infection and distribution of systemic antibiotic treatment. Another advantage of distraction osteogenesis is that it resolves length discrepancy that cannot be solved with vascularized bone transfer and bone grafting methods. The acute shortening method was first

Table. II. — Demographics and outcomes in the segmental bone transport group (LLD = leg length discrepancy)

| Patient | Age (years) | Bone loss (cm) | Segment transport time (days) | Soft tissue defect (cm) | Soft tissue treatment | Follow-up (months) | External fixator index (days/cm) | Bone results | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Union | Grade |
| 1 | 49 | 3.0 | 53 | No | No | 54 | 60.0 | Union | Excellent |
| 2 | 36 | 4.0 | 71 | 5 x 2 | Rotation flap | 54 | 54.8 | Union | Excellent |
| 3 | 43 | 2.0 | 30 | No | No | 84 | 99.0 | Union | Excellent |
| 4 | 43 | 3.0 | 40 | No | No | 45 | 76.0 | Union | Good |
| 5 | 27 | 1.8 | 22 | 3 x 4 | Crossleg flap | 42 | 98.8 | Union | Good |
| 6 | 20 | 10.5 | 200 | No | No | 54 | 49.0 | Union | Excellent |
| 7 | 57 | 2.0 | 35 | No | No | 42 | 58.0 | Union (3 cm LLD) | Good |
| 8 | 41 | 3.0 | 40 | 3 x 5 | Free flap | 39 | 70.0 | Union | Good |
| 9 | 61 | 9.0 | 120 | No | No | 42 | 56.6 | Union | Excellent |
| 10 | 28 | 4.0 | 75 | Skin necrosis | Skin graft | 48 | 105.0 | Nonunion | Fair |
| 11 | 41 | 10.0 | 250 | No | No | 36 | 72.0 | Union | Excellent |
| 12 | 29 | 17.0 | 290 | Skin necrosis | Skin graft | 36 | 15.8 | Nonunion | Fair |
| 13 | 40 | 9.5 | 200 | 2 x 7 | Rotation flap | 42 | 52.1 | Union (10º recurvatum) | Good |
| 14 | 48 | 8.0 | 175 | No | No | 34 | 0 | Nonunion | Fair |
| 15 | 47 | 5.0 | 85 | No | No | 36 | 108.0 | Union | Excellent |
| 16 | 11 | 6.0 | 92 | Skin necrosis | Skin graft | 40 | 53.5 | Union | Excellent |
| 17 | 15 | 7.0 | 75 | No | No | 35 | 96.4 | Union | Excellent |
| 18 | 28 | 12.0 | 145 | No | No | 36 | 35.0 | Nonunion (2 cm LLD, 10º valgus) | Fair |
| 19 | 24 | 8.0 | 176 | 2 x 2 | Rotation flap | 30 | 41.3 | Union | Excellent |
| 20 | 47 | 11.0 | 210 | No | No | 37 | 36.8 | Union | Excellent |
| 21 | 45 | 7.0 | 80 | No | No | 42 | 42.8 | Union | Excellent |
| 22 | 33 | 7.0 | 95 | No | No | 43 | 38.5 | Union | Excellent |
| 23 | 43 | 8.0 | 97 | Skin necrosis | Skin graft | 42 | 45.0 | Union | Excellent |
| 24 | 49 | 3.0 | 53 | No | No | 39 | 60.0 | Union | Excellent |
| 25 | 36 | 4.0 | 71 | No | No | 30 | 54.8 | Union | Excellent |
| 26 | 43 | 2.0 | 30 | No | No | 28 | 99.0 | Union | Excellent |
| 27 | 43 | 3.0 | 40 | No | No | 45 | 76.0 | Union | Excellent |
| 28 | 27 | 1.8 | 22 | No | No | 31 | 98.8 | Union | Excellent |
| 29 | 49 | 3.0 | 35 | No | No | 42 | 76.0 | Union | Excellent |

Table. III. — Demographics and outcomes in the acute shortening and lengthening group (OR = operating room; NAT = no additonal treatment; LLD = leg length discrepancy)

| Patient | Age (years) | Bone loss (cm) | Acute shortening in OR (cm) | Number of additional gradual shortenings | Soft tissue defect (cm) | Soft tissue treatment | Follow-up (months) | External fixator index (days/cm) | Bone results | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Union | Grade |
| 1 | 19 | 8.0 | 3.0 | 4 | No | No | 46 | 38.7 | Union | Excellent |
| 2 | 36 | 6.0 | 3.0 | 3 | 2 x 3 | NAT | 56 | 40.0 | Union | Excellent |
| 3 | 21 | 4.0 | 4.0 | 0 | No | No | 50 | 45.0 | Union | Excellent |
| 4 | 19 | 6.0 | 4.0 | 4 | No | No | 70 | 45.0 | Union | Excellent |
| 5 | 22 | 8.0 | 3.0 | 5 | No | No | 44 | 48.7 | Union | Excellent |
| 6 | 52 | 5.0 | 3.0 | 0 | No | No | 53 | 66.0 | Union | Excellent |
| 7 | 41 | 3.0 | 2.0 | 0 | 2 x 3 | NAT | 120 | 60.0 | Union (valgus) | Good |
| 8 | 50 | 4.0 | 3.0 | 3 | 2 x 2 | NAT | 42 | 50.0 | Union (1 cm LLD) | Excellent |
| 9 | 18 | 5.0 | 3.0 | 2 | No | No | 40 | 36.0 | Union | Excellent |
| 10 | 32 | 5.0 | 4.0 | 4 | 2 x 2 | NAT | 58 | 48.7 | Union | Excellent |
| 11 | 48 | 6.0 | 4.0 | 2 | No | No | 64 | 38.5 | Union | Excellent |
| 12 | 37 | 5.0 | 3.0 | 2 | No | No | 74 | 60.0 | Union (3 cm LLD) | Good |
| 13 | 41 | 4.0 | 4.0 | 0 | No | No | 78 | 45.0 | Union | Excellent |
| 14 | 35 | 4.0 | 4.0 | 0 | 3 x 4 | NAT | 65 | 48.0 | Union | Excellent |
| 15 | 47 | 6.0 | 4.0 | 2 | 4 x 3 | NAT | 45 | 56.2 | Union | Excellent |
| 16 | 50 | 6.0 | 3.0 | 3 | No | No | 59 | 70.0 | Union | Excellent |
| 17 | 24 | 4.0 | 4.0 | 0 | 2 x 3 | NAT | 24 | 52.5 | Union | Excellent |
| 18 | 54 | 3.0 | 3.0 | 0 | No | No | 24 | 54.0 | Union | Excellent |
| 19 | 38 | 4.0 | 4.0 | 0 | 2 x 4 | NAT | 58 | 45.0 | Union | Excellent |
| 20 | 44 | 9.0 | 7.0 | 0 | No | No | 84 | 30.0 | Union | Excellent |
| 21 | 43 | 12.0 | 6.0 | 4 | No | No | 35 | 22.5 | Union | Excellent |
| 22 | 23 | 8.0 | 5.0 | 0 | 2 x 1 | NAT | 41 | 48.0 | Union (10° procurva-tum) | Good |
| 23 | 10 | 8.0 | 5.0 | 0 | No | No | 61 | 35.6 | Union | Excellent |
| 24 | 18 | 5.0 | 3.0 | 0 | 2 x 3 | NAT | 24 | 30.0 | Union | Excellent |
| 25 | 20 | 3.0 | 6.0 | 0 | No | No | 60 | 110.0 | Union | Excellent |
| 26 | 42 | 6.0 | 7.0 | 3 | 3 x 2 | NAT | 80 | 50.0 | Union | Excellent |
| 27 | 28 | 12.0 | 3.0 | 0 | No | No | 14 | 32.5 | Union | Excellent |
| 28 | 33 | 8.0 | 3.0 | 0 | 7 x 3 | Free vas-cularized flep | 19 | 50.6 | Union | Excellent |

| Patient | Age (years) | Bone loss (cm) | Acute shortening in OR (cm) | Number of additional gradual shortenings | Soft tissue defect (cm) | Soft tissue treatment | Follow-up (months) | External fixator index (days/cm) | Bone results | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Union | Grade |
| 29 | 34 | 7.0 | 4.0 | 0 | 2 x 3 | NAT | 29 | 70.7 | Union (7° valgus) | Good |
| 30 | 40 | 8.0 | 6.0 | 0 | 2 x 2 | NAT | 24 | 39.3 | Union (1 cm LLD) | Excellent |
| 31 | 53 | 6.0 | 8.0 | 0 | No | No | 36 | 45.0 | Union | Excellent |
| 32 | 37 | 10.0 | 5.0 | 0 | 2 x 2 | NAT | 40 | 27.0 | Union | Excellent |
| 33 | 62 | 5.0 | 5.0 | 0 | No | No | 20 | 57.0 | Union | Excellent |
| 34 | 46 | 5.0 | 7.0 | 0 | No | No | 32 | 48.0 | Union (3 cm LLD + (10° valgus) | Fair |
| 35 | 19 | 7.0 | 3.0 | 4 | No | No | 36 | 47.1 | Union | Excellent |
| 36 | 36 | 8.0 | 3.0 | 3 | 3 x 4 | NAT | 24 | 38.7 | Union | Excellent |
| 37 | 21 | 6.0 | 4.0 | 0 | 4 x 3 | NAT | 16 | 40.0 | Union | Excellent |
| 38 | 19 | 4.0 | 4.0 | 4 | No | No | 26 | 45.0 | Union | Excellent |
| 39 | 22 | 6.0 | 3.0 | 5 | 2 x 3 | NAT | 16 | 45.0 | Union | Excellent |
| 40 | 52 | 8.0 | 3.0 | 0 | No | No | 22 | 48.7 | Union | Good |
| 41 | 41 | 5.0 | 2.0 | 0 | 2 x 4 | NAT | 12 | 66.0 | Union | Good |
| 42 | 50 | 3.0 | 3.0 | 3 | No | No | 24 | 60.0 | Union | Good |
| 43 | 18 | 4.0 | 3.0 | 2 | No | No | 16 | 50.0 | Union | Excellent |
| 44 | 37 | 5.0 | 5.0 | 0 | 2 x 1 | NAT | 40 | 36.0 | Union (10° cm procur-vatum + 2 cm LLD ) | Fair |
| 45 | 32 | 7.0 | 4.0 | 3 | No | No | 25 | 60.0 | Union | Good |

Table. IV. — Comparison of outcome parameters between the two groups (*Analyzed by Mann-Whitney U test.)

| Parameter | Segmental bone transport group | Acute shortening and lengthening group | P value* |
|---|---|---|---|
| External fixator index (days/cm) | 62.6 (range 44-108) | 48.39 (Range 22,5-110) | 0.01 |
| Number of complications/patient (Mean) | 1.28 (Range 0-4) | 1.31 (Range 0-3) | 0.163 |

described by Giebel as a case report in the treatment of tibial pseudarthrosis with bone loss (18). Sen et al. (20) later reported on acute shortening and relengthening through an osteotomy at the healthy site of the bone for the treatment of the tibial pseudarthrosis with bone loss. They reported an EFI of 1.4 months/cm in their acute compression and distraction series of 17 patients, with a mean bone loss of 5.6 cm. Saleh and Rees (19) compared the results of compression-distraction versus bone transport in the treatment of pseudarthrosis with bone loss. The total treatment time was 9.8 months and 16 months, respectively. They reported different results in terms of treatment time and complications because they did not perform resection of the nonunion site and they included both femoral and tibial pseudarthroses in their study.

This study had a number of limitations. First, the surgeon's preference for the treatment strategies could not be standardized because this is a multicenter retrospective study and clinical records were used from the practices of different surgeons. Selection bias is almost unavoidable in this setting. The second limitation for the study was the retrospective evaluation of the patients using chart review. This can result in assessor bias; unfortunately, bringing the patients from different parts of the country to the main center was impractical. Because the radiologic information of the patients was obtained from the centers, this should help to offset some of the assessor bias in terms of bone score and external fixator time, but functional scoring could certainly be influenced by the treating teams. Finally, as these patients' procedures were performed over a long period of time, and included some of the authors' learning curves with the techniques, some techniques (including the use of bone grafts) varied over the period of study, and the influence of this may be difficult to discern.

There was no difference between the two techniques in terms of the Paley functional and bone scoring system. This suggests that both bone segment transport and acute compression and lengthening techniques can be used safely for the treatment of Cierny-Mader Type IV osteomyelitis. Acute shortening of more than 7 cm and relengthening from a different part of the bone segment can adversely effect muscle function. In our series although there was no difference in functional scores between the two groups, one should not forget that shortening from the tendinous part and lengthening from sarcomere region of the muscle can adversely affect the function of the extremity, especially for defects more than 7 cm.

The acute compression and distraction technique had better external fixator index scores than bone transport. The resection of the infected site with unhealthy bone enables viable bone at each site of docking acutely in this group; however, in the segmental bone group, the transported segment loses viability because of the huge defect size and long transport time. Docking sides become avascular during transport (15,21). Group 2 required less bone grafting compared with group 1, and because there were no nonunions in the former group, the treatment period and consolidation time was longer in the latter group. Studies on segment transport with circular external fixators with infected nonunions report a mean external fixator index of 54.9 days/cm. This is less than in our segment transport group (62.6 days/ cm), and more than our acute compression and distraction group (48.4 days/ cm) (8).

There was no difference between the groups in terms of the number of complications per patient. Complications were relatively frequent events in both groups, reflecting the complex clinical problems we treated using these surgical approaches, but the number of complications were not significantly different between the two treatment groups. The complication rate was much less in group 2 than in group 1. We believe the lower rate of complications also contributes to shortening the treatment time (13,15,21). The complications were most commonly related to docking site problems, which is compatible with the literature (1,2,3,7,8,9,10,13,17,21). These problems were soft tissue invagination, malalignment, reinfection, and most commonly, nonunion. Thus, we recommend routine autologous cancaleous grafting of the docking site at the time of docking as a routine part of the for segmental bone transport procedure.

In conclusion, although the number of complications and Paley scores for bone or function were not different with the numbers available in the two treatment groups, the acute shortening and lengthening method provided a shorter external fixator index than the segmental bone transport method. We attribute this difference mostly to problems related to the docking site, and a longer time for the transport in the segmental bone transport group. Although both techniques can be used for treatment of Cierny-Mader Type IV osteomyelitis in the tibia, the acute compression technique may provide greater patient satisfaction because of the shorter external fixator index, although future studies will be needed to determine whether this is, in fact, the case.

## REFERENCES


1. **Aronson J**. Limb lengthening skeletal reconstruction and bone transport with the Ilizarov method. *J Bone Joint Surg Am.* 1997;79:1243-1258.
2. **Atesalp AS, Basbozkurt M, Erler K,sehirlioğlu A, Tunay S, Solakoğlu C, Gür E** Treatment of tibial bone defects with the Ilizarov circular external fixator in high-velocity gunshot wounds. *Int Orthop.* 1998;22:342-347.
3. **Catteneo R, Catagni M, Johnson EE**. The treatment of infected nonunions and segmental defects of the tibia by the methods of Ilizarov. *Clin Orthop Relat Res.* 1992;280:143-152.
4. **Cierny G 3rd**. Infected tibial non-union (1981–1995): the evolution of change. *Clin Orthop Relat Res.* 1999;360:97-105.
5. **Cierny G 3rd, Mader JT, Penninck JJ**. A clinical staging system for adult osteomyelitis. *Clin Orthop Relat Res.* 2003;414:7-24
6. **Cierny G 3rd, Zorn KE**. Segmental tibial defects: comparing conventional and Ilizarov methodologies. *Clin Orthop Relat Res.* 1994;301:118-123.
7. **Dagher F, Roukoz S.** Compound tibial fractures with bone loss treated by the Ilizarov technique. *J Bone Joint Surg Br.* 1991:73:316-321.
8. **Dendrinos GK, Kontos S, Lyritsis E.** Use of the Ilizarov technique for treatment of non-union of the tibia associated with infection. *J Bone Joint Surg Am.* 1995;77:835-846.
9. **Green SA, Jackson JM, Wall DM, Marinow H, Ishkanian J**. Management of segmental defects by the Ilizarov intercalary bone transport method. *Clin Orthop Relat Res.* 1992;280:136-142.
10. **Ilizarov GA.** Clinical application of tension-stress effect to limb lengthening. *Clin Orthop Relat Res.* 1990;250:8-26.
11. **Liu T, Zhang X, Li Z, Peng D**. Management of combined bone defect and limb length discrepancy after tibial chronic osteomyelitis. Orthopaedics. 2011;34:e363-e367.
12. **Kocaoglu M, Eralp L, Rashid HU, Sen C, Bilsel K**. Reconstruction of segmental defects due to chronic osteomyelitis with use of an external fixator and an intramedullary nail. *J Bone Joint Surg Am.* 2006;88:2137-2145.
13. **Marsh JL, Prokuski L, Biemann JS**. Chronic infected tibial nonunions with bone loss. *Clin Orthop Relat Res.* 1994;301:139-146.
14. **Paley D.** Problems, obstacles and complication of limb lengthening by the Ilizarov technique. *Clin Orthop Relat Res.* 1990;250:81-104.
15. **Paley D, Catagni MA, Argnani F, Villa A, Benedetti GB, Cattaneo R**. Ilizarov treatment of tibial nonunions with bone loss. *Clin Orthop Relat Res.* 1989;241:146-165.
16. **Paley D, Maar DC**. Ilizarov bone transport treatment for tibial defects. *J Orthop Trauma.* 2000;14:76-85.
17. **Polyzois D, Papachristou G, Kotsiopoulos K, Plessas S**. Treatment of tibial and femoral bone loss by distraction osteogenesis. *Acta Orthop Scand Suppl.* 1997;275:84-88.
18. **Rozbruch SR, Weitzman AM, Watson JT, Freudigman P, Katz HV, Ilizarov S**. Simultaneous treatment of tibial bone and soft-tissue defects with the Ilizarov method. *J Orthop Trauma.* 2006;20:197-205.
19. **Saleh M, Rees A**. Bifocal surgery for deformity and bone loss after lower-limb fractures. *J Bone Joint Surg Br.* 1995;77:429-434
20. **Sen C, Eralp L, Gunes T, Erdem M, Ozden VE, Kocaoglu M**. An alternative method for the treatment of nonunion of the tibia with bone loss. *J Bone Joint Surg Br.* 2006;88:783-789.
21. **Song HR, Cho SH, Koo KH, Jeong ST, Park YJ, Ko JH**. Tibial bone defects treated by internal bone transport using the Ilizarov method. *Int Orthop.* 1998;22:293-297
22. **Watson T.J**. Distraction osteogenesis. *J Am Acad Orthop Surg* 2006;14:168-174