Distal Tibial Reconstruction with Use of a Circular External Fixator and an Intramedullary Nail

The Combined Technique

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Background: Distal tibial reconstruction with use of an external fixator when there is bone loss, limb-length discrepancy, and/or ankle instability is associated with many problems. The technique of limb-lengthening, ankle arthrodesis, and segmental transfer over an intramedullary nail has been introduced to overcome these problems. The present study investigates this combined technique.

Methods: Between 2002 and 2005, six patients, who ranged from seventeen to seventy years old, underwent distal tibial reconstruction and ankle arthrodesis with use of a circular external fixator and an intramedullary nail to treat a distal tibial defect following resection for chronic osteomyelitis or tumor or to treat a limb-length discrepancy combined with ankle instability. Functional and radiographic results were evaluated, with use of the criteria described by Paley et al., at an average follow-up of thirty-four months.

Results: The mean size of the bone defects in three patients was 5.3 cm (2, 7, and 7 cm), and the mean amount of the limb-shortening in four patients was 5.25 cm (range, 4 to 6 cm). The mean external fixation time was 3.5 months, and the mean external fixator index was 0.57 mo/cm. There was no recurrence of infection in the two patients with osteomyelitis. All six patients had excellent bone results, and the functional results were excellent for two patients and good for four patients. There were four complications, three of which were categorized, according to Paley, as a problem (a difficulty that occurs during lengthening and is resolved without operative intervention) and one that was categorized as an obstacle (a difficulty that occurs during lengthening and needs operative treatment).

Conclusions: The combined technique is an improvement over the classic external fixation techniques of distal tibial reconstruction with ankle arthrodesis. It reduces the duration of external fixation, thus increasing patient acceptance, and it is associated with a low complication rate facilitating more rapid rehabilitation.

Level of Evidence: Therapeutic Level IV. See Instructions to Authors for a complete description of levels of evidence.

Reconstruction of the distal end of the tibia with an unstable ankle joint, bone loss, and/or limb-length discrepancy is a challenging task for the orthopaedic surgeon. Custom-made ankle replacements and other surgical procedures combining allograft, free-tissue transfer, and ankle arthrodesis with limb-lengthening or bone transport with use of a circular external fixator have been utilized to treat this condition[1-16]. The use of a circular external fixator to achieve an ankle arthrodesis was initially described to overcome the complicating problems of infection, deformity, and/or osteoporotic bone[3]. Subsequently, the fixator has been used to achieve an ankle arthrodesis in the presence of bone loss and a leg-length discrepancy[1,9,13-16].

Although all of these challenging problems can be addressed by the use of a circular external fixator, this method has been associated with many complications. Pin-site infection, refracture, nonunion, malunion, and loss of alignment have been reported in many series[1,3,5,9,13-16].

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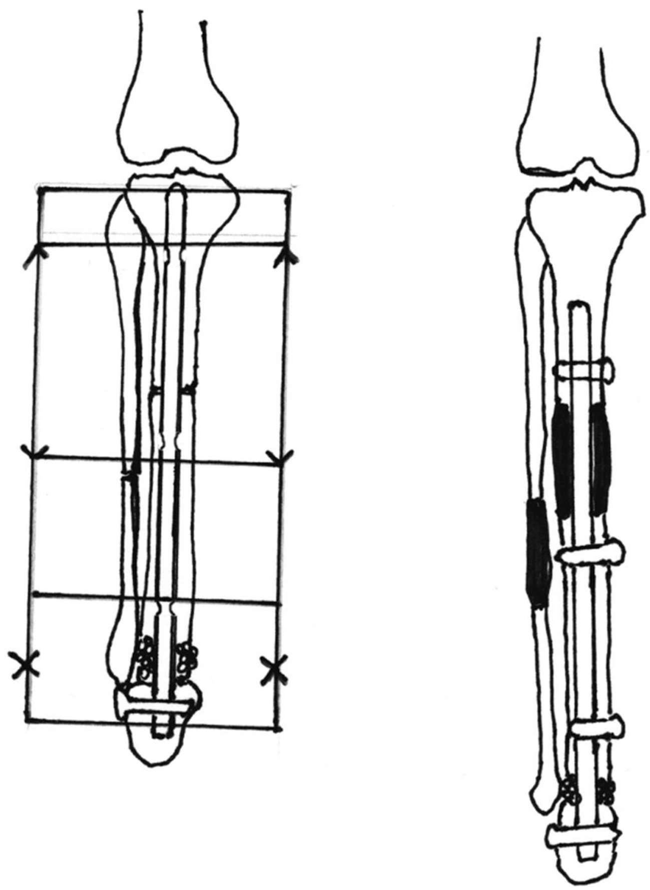

Fig. 1

Drawings showing the construct for lengthening and ankle arthrodesis over an intramedullary nail. Prior to the first stage, transverse screwholes in the intramedullary nail are predrilled at the planned site of locking after lengthening has been completed. The bone graft is packed at the arthrodesis site. The distraction is done between the two proximal rings, and compression is done at the arthrodesis site. After the desired leg length has been achieved, the external fixator is removed and locking screws are inserted in the proximal part of the tibia and through the predrilled holes in the nail in the lengthened tibia.

In order to reduce these complications, we used the circular external fixator in combination with an intramedullary nail to achieve ankle arthrodesis, bone transport, and/or leg-lengthening in selected patients. This method allows for earlier removal of the circular external fixator while the intramedullary nail protects the regenerated bone and the ankle arthrodesis from angulation and displacement.

The present retrospective study summarizes our experience using the combination of a circular external fixator and an intramedullary nail for the reconstruction of the distal end of the tibia and the ankle.

Materials and Methods

Between 2002 and 2005, six patients were managed with the combined technique. Three of them underwent ankle arthrodesis and bone transport and the other three underwent ankle arthrodesis and tibial lengthening with use of a circular external fixator and an intramedullary nail. The average age of the patients at the time of the procedure was 28.7 years (range, seventeen to seventy years). The average size of the tibial bone defect in three patients was 5.3 cm (2, 7, and 7 cm), and the average amount of shortening in four patients was 5.25 cm (range, 4 to 6 cm).

Two patients (Cases 3 and 4) had a distal tibial defect following the resection of osteomyelitis (type IVB in the Cierny-Mader classification system)[17]. One of them (Case 3) also had 6 cm of shortening. Another patient (Case 1) had a distal tibial defect following resection of desmoid fibroma. A fourth patient (Case 2), treated initially during childhood, had 5 cm of shortening of the tibia with a pes calcaneovalgus deformity, following resection of the sciatic nerve to treat fibrosarcoma. One patient (Case 5) had sequela of poliomyelitis, and one (Case 6) had fibular hemimelia.

Demographic data were collected after reviewing the medical record and the registry maintained in our department of the patients undergoing distraction osteogenesis. All pa-

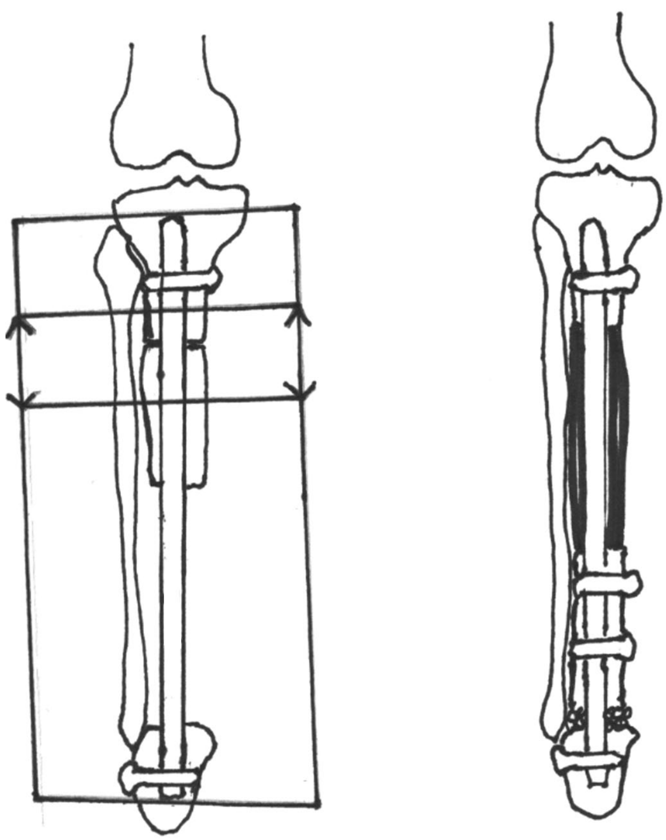

Fig. 2

Drawings showing the construct for segmental transfer and ankle arthrodesis over an intramedullary nail. After the transferred segment has docked at the talus, the external fixator is removed, the arthrodesis site is packed with bone graft, and locking screws are inserted in the predrilled hole in the intramedullary nail within the transferred segment.

tients were assessed for local skin condition, shortening, deformity, distal neurovascular status, and joint function.

The results were divided into two categories, bone results and functional results, according to the classification system of Paley et al.[1,18] (see Appendix). The complications were evaluated according to the criteria described by Paley[19].

Operative Technique

The operative procedure for osteomyelitis was done in two stages as described by Kocaoglu et al.[20]. During the first stage, radical débridement with bone resection was done in the two patients with chronic osteomyelitis. In the remaining patients, all procedures were done during the same operation.

The procedure is performed under tourniquet control with the patient in the supine position on a radiolucent operating table. Initially, the subtalar joint is prepared for arthrodesis through a small incision placed over the sinus tarsi. The foot is then positioned in correct alignment for ankle arthrodesis. A threaded Kirschner wire is inserted through the plantar aspect of the calcaneus, and the entry point for intramedullary nail insertion is determined with use of an image intensifier. A cannulated drill is then inserted over the Kirschner wire to enlarge the hole for the insertion of the guidewire. After preparing the entry site, reaming is performed progressively over a guidewire in 0.5-mm increments.

Additional holes are predrilled in the nail (TRIGEN tibial nail; Smith and Nephew, Memphis, Tennessee) at the planned site of locking of the segment upon the completion of bone transport to prevent recoil of the segment. A corticotomy is done at the appropriate level with use of a Gigli saw.

After the medullary canal has been overreamed by 2 mm, the intramedullary nail is inserted and the distal part is locked. For bone segment transfers, both ends are locked. For the patient with shortening, an intramedullary nail of the eventual desired length of the tibia is inserted and left proud proximally so that it can slide distally during treatment.

The circular external fixator construct is prepared preoperatively on the basis of biplanar radiographs. For lengthening, two circular rings for the proximal part of the tibia, two rings distal to the osteotomy site, and one foot frame are as-

Fig. 3-A

Fig. 3-B

Fig. 3-C

Figs. 3-A through 3-H Case 4, a seventy-year-old man with chronic osteomyelitis of the distal third of the left tibia. **Fig. 3-A** Photograph made when the patient was first seen by us showing an open fracture with a wound over the anterolateral aspect of the left leg. **Fig. 3-B** Plain radiograph made at presentation showing the pilon fracture, which had not united. **Fig. 3-C** Radiograph made after radical débridement and resection of infected bone followed by insertion of antibiotic beads. The bone is stabilized with a spanning external fixator.

sembled. The site of the ankle arthrodesis is packed with autologous bone graft, and compression is applied with use of the ring external fixator. The circular frames are removed after the lengthening is completed. The locking screws are then inserted in the proximal part of the tibia and the lengthened segment (Fig. 1).

In the case of segment transfer, three circular rings are assembled for the proximal part of the tibia with one ring acting as a transport segment. It is connected with the foot frame distally. Autologous bone graft is packed at the docking site after the transported segment has docked with the talus. The docking site is compressed and locked with use of the custom-drilled holes in the rod before removal of the external fixator (Fig. 2).

Postoperative Care and Follow-up

Distraction is started between the seventh and the tenth postoperative day. The rate of the distraction is 1 mm/day, divided into four equal increments. An epidural catheter is placed for postoperative pain management for five days, and range-of-motion exercises of the knee are initiated as soon as the comfort of the patient allows. Full weight-bearing with two crutches is started immediately.

In the outpatient clinic, patients are screened for signs and symptoms of local infection. The C-reactive protein level and the erythrocyte sedimentation rate are monitored serially in patients who have undergone resection for osteomyelitis. Conventional radiographs are made every two weeks during the distraction phase and once a month during the consolidation phase.

The external fixation index is calculated as the duration of external fixation in months divided by the total amount of bone transported and/or the amount of lengthening in centimeters.

Results

Six patients treated with the combined technique were followed for a mean of thirty-four months (range, fourteen

Fig. 3-D

Fig. 3-E

Fig. 3-F

Fig. 3-D Postoperative anteroposterior radiograph showing the intramedullary nail and the circular external fixator. Both the distal and the proximal screws of the intramedullary nail are locked. **Fig. 3-E** Postoperative lateral radiograph showing the intramedullary nail passing through the calcaneus, talus, and tibia. **Fig. 3-F** Anteroposterior radiograph made after the transferred segment was docked with the talus. The external fixator had been removed, and the locking screws had been inserted at the predrilled holes in the intramedullary nail.

Fig. 3-G

Fig. 3-H

Fig. 3-G Anteroposterior radiograph showing union at the arthrodesis site. **Fig. 3-H** Lateral radiograph showing union at the arthrodesis site.

to fifty-one months). The mean external fixation time was 3.5 months (range, two to five months). The mean external fixator index was 0.57 mo/cm (range, 0.4 to 0.8 mo/cm). Union was achieved in all patients, and there was no recurrence of infection in the two patients treated for osteomyelitis (Figs. 3-A through 3-H).

Using the criteria described by Paley et al., we achieved excellent bone results in all six patients. The functional results were good for four patients and excellent for two. The scores are shown in Table I.

We observed four complications, which included three that were categorized according to Paley as problems (a difficulty that occurs during lengthening and is resolved without operative intervention) and one that was categorized as an obstacle (a difficulty that occurs during lengthening and needs operative treatment). One patient had a minor pin-tract infection, which resolved with local wound care and antibiotics. One patient had pain during distraction, which resolved with analgesic medication. One experienced reflex sympathetic dystrophy after frame removal, which resolved with appropriate medication and rehabilitation. One patient had irritation at a locking screw, which was removed under local anesthesia.

Discussion

Reconstruction after distal tibial bone loss with ankle involvement remains a therapeutic challenge to orthopaedic surgeons. In order to achieve a stable plantigrade foot without limb-length discrepancy, various methods have been used[1-16,21-23]. Reconstruction with use of a custom-made endoprosthetic ankle implant in tumor patients has had a high complication rate[21-23]. Problems with deep infection, talar collapse, and deterioration of function over time have limited the use of the technique in this group of patients. Arthrodesis of the ankle has become an accepted method to reconstruct the ankle joint[1-16]. Moore et al. described reconstruction of the ankle with use of allograft and arthrodesis with an intramedullary nail following resection of a distal tibial tumor in nine patients[10]. Allograft fracture and nonunion at the allograft-host junction were problems in that series. Finally, free tissue transfer either with an osteocutaneous flap or with a muscle flap followed by the placement of autologous bone graft has been performed in a small number of patients in centers with microsurgical capabilities[4,11,12]. The use of a circular external fixator has been associated with many complications often requiring additional surgical procedures[1,3,9,13-15]. Johnson et al. used a circular external fixator as a compressive device to achieve ankle arthrodesis and deformity correction in a group of six patients with a rigid valgus deformity and destruction of the talus[3]. Union was achieved in five patients. Four patients had an infection, but it had resolved at the time of the final follow-up. One patient had a refracture at the arthrodesis site. Six wires broke and required reinsertion.

Hawkins et al. used a circular external fixator to achieve arthrodesis and restore length in ten patients with tibial osteomyelitis[9]. All except one of them achieved union at the arthrodesis site, and only one had 3 cm of residual limb-length discrepancy. Seventeen surgical procedures are done for frame or pin revisions, additional bone-grafting, corticotomy, or internal fixation at the tibiotalar joint.

Katsenis et al. performed ankle arthrodesis and limb-lengthening in twenty-one patients, and all achieved union at the arthrodesis site[1]. Two of the patients had a residual limb-length discrepancy of >2 cm. Seventeen additional procedures were done, and they included osteotomy, repeat corticotomy, wire exchange, débridement, bone-grafting, and tarsal tunnel release.

The problems of a long duration of external fixation, pin-site infection, and loosening have led many surgeons to search for an alternative method of ankle arthrodesis when there is structural bone loss. The use of an intramedullary nail has gained acceptance in achieving an ankle arthrodesis when there is a substantial amount of bone loss such as occurs in the treatment of a failed total ankle replacement[6-8,24]. The intramedullary nail provides better stability than conventional screw fixation. This helps to maintain alignment until union is achieved[25].

The cause of nonunion in ankle arthrodesis is commonly related to problems of the talus, and traditional screw fixation usually fails because the talus collapses. Furthermore, the subtalar joint is also frequently involved in patients with posttraumatic arthritis. Retrograde nail fixation is an excellent method to achieve a tibiotalocalcaneal arthrodesis[6-8,24,26]. However, it does not correct limb-length discrepancy, and it is contraindicated in the presence of active infection.

The insertion of an interlocking nail after lengthening or segmental transport has been done to overcome the problems of shortening, plastic deformation, and fracture of the regenerated bone following removal of the circular external fixator. However, it requires an additional operation and increases the duration of treatment[13]. To overcome this problem, we used bone transport and lengthening over a nail and had successful results. The technique reduces the external fixation time by almost half, while not reducing the consolidation index, and it protects the regenerated bone from plastic deformation and fracture[27,28]. We have also used this method successfully to reconstruct defects following resection of previously infected bone, but only when the infection had been eliminated before the procedure was performed[20].

This technique reduces the external fixation time because the external fixator is removed immediately after the distraction phase. The mean duration of external fixation in our patients (0.57 mo/cm) was much lower than those reported by Sakurakichi et al., who used the Ilizarov frame alone (4.8 mo/cm in the compression-distraction group and 1.18 mo/cm in the bone transport group)[13]. Early removal of the frame also leads to fewer complications. Thus, the intramedullary rod allows earlier frame removal and provides extra stability for the reconstruction.

TABLE I Demographic and Outcome Data on the Study Patients

Case	Gender, Age	Diagnosis	Bone Defect Size *(cm)*	Shortening *(cm)*	External Fixation Time *(mo)*	External Fixator Index *(mo/cm)*	Final Bone Status	Final Functional Status	Complications
1	F, 20	Desmoid fibroma at distal end of tibia	7	0	4	0.6	Excellent	Good	Reflex sympathetic dystrophy treated medically
2	M, 17	Postresection of sciatic nerve embedded in fibrosarcoma during childhood	0	5	2	0.4	Excellent	Excellent	Nerve pain resolved with analgesia
3	F, 18	Cierny-Mader grade-IVB chronic osteomyelitis of tibia (after radiation therapy)	2	6	4	0.5	Excellent	Good	Irritation of locking screw; removed under local anesthesia
4	M, 70	Cierny-Mader grade-IVB chronic osteomyelitis of tibia (atherosclerosis)	7	0	4	0.6	Excellent	Excellent	Minor pin-tract infection resolved with antibiotics
5	F, 30	Poliomyelitis	0	4	2	0.5	Excellent	Good	None
6	M, 17	Fibular hemimelia	0	6	5	0.8	Excellent	Good	None

This series is the first, as far as we know, to describe simultaneous arthrodesis, lengthening, and/or segment transfer with use of the combined technique. It is a valuable alternative to the classic distal tibial reconstruction with use of a circular external fixator. Our results are comparable with other techniques in terms of functional outcome and safety and are superior in terms of treatment time and external fixator index.

Appendix

eA A table showing the evaluation criteria of Paley et al. is available with the electronic versions of this article, on our web site at jbjs.org (go to the article citation and click on "Supplementary Material") and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM). ■

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