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Original article

Tibial lengthening over an intramedullary nail

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Abstract

Background. Long-term application of an external fixator to treat leg-length discrepancy and short stature often causes complications, such as pin-tract infection or loss of range of motion at the knee or ankle (or both). Prolonged fixator use also interferes with the activities of daily living. To minimize such problems, we have combined intramedullary nailing with external fixation. Using this technique, the external fixator can be removed more quickly after completing the lengthening.

Methods. We combined intramedullary nailing with lengthening in 13 tibias (8 patients) and then compared these cases with 17 standard tibial lengthenings (16 patients) using an external fixator alone. In both groups we excluded patients who had a history of previous bone infection, open fracture, immature bone, soft tissue compromise, antineoplastic chemotherapy, or bone deformity of a severity that required gradual deformity correction. We also excluded cases with lengthening of less than 3 cm.

Results. The mean external fixation index differed significantly between the two groups, but the consolidation index did not. Mean operating time for lengthening combined with intramedullary nail placement was approximately 60 min longer than for standard lengthening without nail placement; intraoperative blood loss was not greater in the nailing group. Complications related to the external fixator were far fewer in the combined intramedullary nailing and lengthening group compared with the control group, and callus formation was satisfactory for both groups.

Conclusions. A combination of intramedullary nailing and external fixation produces callus formation as good as that obtained by the standard Ilizarov method of lengthening. Furthermore, this combined procedure decreases the external fixation time and is associated with fewer complications.

Introduction

Distraction osteogenesis, widely used for leg lengthening[1–5] and filling bone defect,[5–11] often requires a long period of external fixation. Such treatment has two distinct phases: distraction and consolidation. The consolidation phase lasts approximately twice as long as the distraction phase in children and up to four times as long in adults.[12,13] Patients often tolerate the consolidation period poorly, and complications such as pin-tract infections and stiffness of the joint may develop. On the other hand, if the external fixator is removed too early, the regenerated bone fractures, resulting in one or more of the following complications: deformity, shortening, nonunion.[14]

In 1997, Paley et al. described a technique of bone lengthening over an intramedullary nail to provide a more comfortable lengthening process, shorten the external fixation period, and support the regenerated bone internally.[15] This technique is gaining wider acceptance because of the improvement in patient comfort.[16,17] On the other hand, Kristiansen and Steen reported encountering a high rate of serious complications in patients treated with tibial lengthening over an intramedullary nail, leading them to abandon this technique and return to the classic Ilizarov method.[18]

In the present study we retrospectively compared a group of cases treated with tibial lengthening over an intramedullary nail with another group of cases treated with tibial lengthening by an external fixator alone. We also evaluated the complications associated with the two methods.

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Table 1. Background of IMN and control patients

Parameter	IMN group	Control group
Tibias/patients	13/8	17/16
Age (years), mean ± SD (range)	22.2 ± 10.3 (14–53)	14.6 ± 7.6 (4–35)
Sex (female : male)	6 : 2	6 : 10
Etiology (no. of cases)		
Limb-length discrepancy	3[a]	15[b]
Dwarfism	5	1
External fixator and no. of tibias	Ilizarov 6/Orthofix 7	Ilizarov 7/Orthofix 10

IMN, intramedullary nail; LLD, limb-length discrepancy
[a] Includes growth plate arrest ($n = 1$) and tumor excision ($n = 2$)
[b] Includes growth plate arrest ($n = 6$), trauma ($n = 1$), congenital LLD ($n = 7$), and Ollier's disease ($n = 1$)

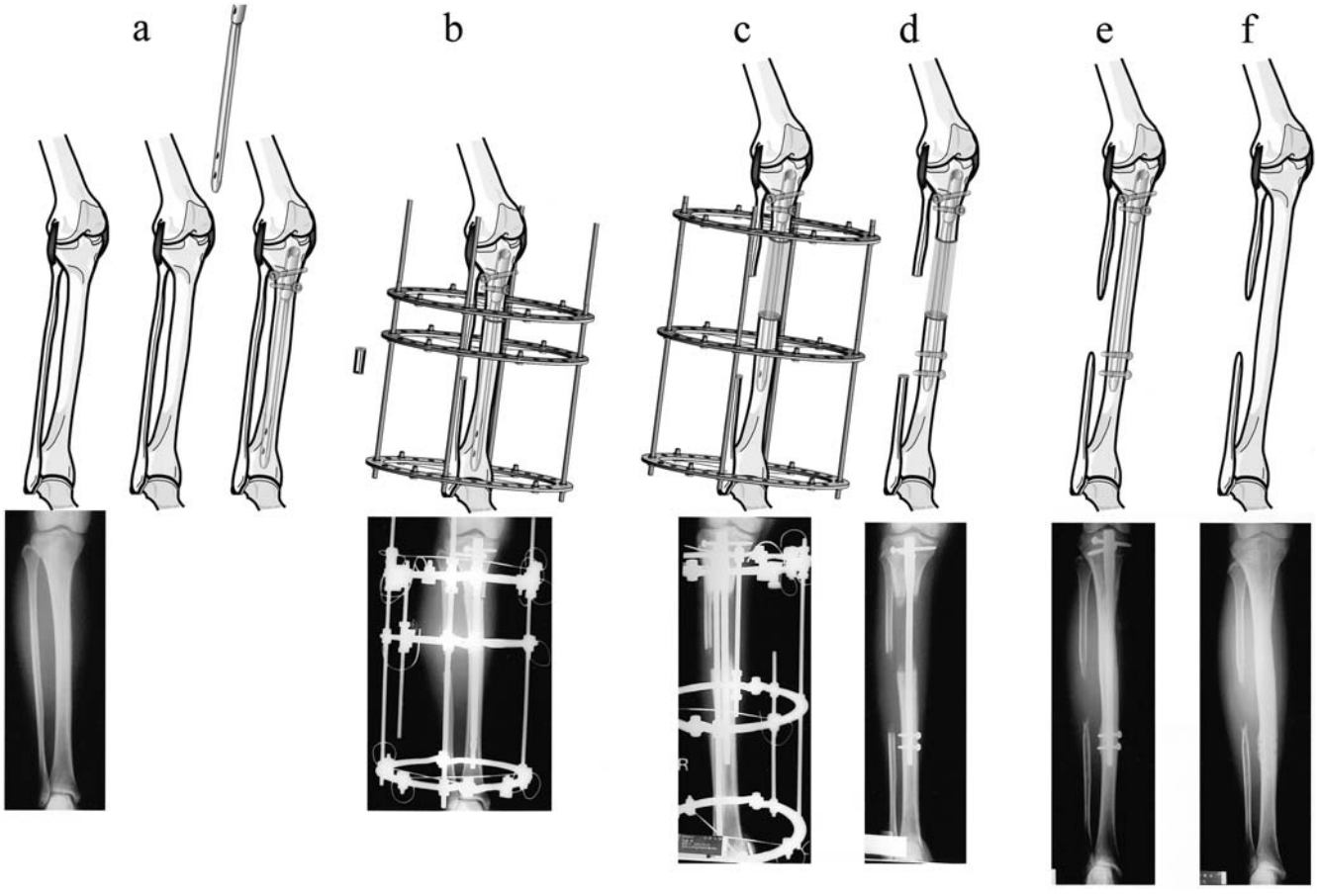

Fig. 1. Sequence of procedures and distraction for lengthening by an external fixator over an intramedullary nail. *Top*, diagrams of radiograph and pictures on the *bottom*. **a** Nailing, **b** Fixator application. **c** Distraction. **d** Distal screw placement followed by fixator removal. **e** Completion of new bone maturation. **f** Screw and nail removal

Patients and methods

Intramedullary nailing group

We performed tibial lengthening over an intramedullary nail for a total of 13 segments in eight patients: Five patients underwent a bilateral procedure, and the other three had a unilateral procedure (Table 1; Fig. 1). We performed these procedures in patients with mature bones without deformity or infection. The mean duration of follow-up was 3.5 years (range 1.2–6.2 years). The mean age of patients at the time of operation was

22.2 years (range 14–53 years). Six patients were female, and two were male. Three patients underwent lengthening due to limb-length discrepancy, and five were treated for short stature.

The Ilizarov external fixator (Smith and Nephew, Memphis, TN, USA) was used in six tibias, and the Orthofix external fixator (Orthofix S.R.L., Bussolengo-Verona, Italy) was used in seven. We initially preferred to use the Orthofix external fixator because a unilateral external fixator is more comfortable for patients. However, in some patients whose intramedullary canal was narrow we encountered difficulty attaching the Orthofix external fixator because of the small amount of space available for inserting half-pins after intramedullary nailing. Thus, from 1997 on, we used the Ilizarov external fixator in all cases of tibial lengthening over an intramedullary nail.

The Russell-Taylor Delta nail (Smith and Nephew) with a diameter of 8 mm was used for nine tibias in seven patients; the Unreamed Humeral nail (Mathys, Bettlach, Switzerland) with a diameter of 6.7 mm was used for two tibias in one patient; and the M/DN nail (Zimmer, Warsaw, IN, USA) with a diameter of 7 mm was used for two tibias in one patient. Because we sought to leave as much space as possible for inserting half-pins or wires, we used the Unreamed Humeral nail or the M/DN nail in cases of narrow intramedullary canal.

Operative procedure and postoperative care

After drilling multiple wire-holes at the planned osteotomy site to prevent fat embolism related to intramedullary nailing, we inserted the intramedullary nail with proximal interlocking screws. The osteotomy was completed with an osteotome using multiple wire-holes. The level of the osteotomy depended on the planned amount of lengthening and on the initial length of the tibia. We ensured that at least 8 cm of the nail was on the distal side of the distraction gap at the end of lengthening. With the nail in place, an external fixator was applied for lengthening. All external fixation pins and wires were inserted without contact with the intramedullary nail. Distraction began 7 days postoperatively at a rate of 0.25 mm four times a day or 0.5 mm twice a day. During lengthening, radiographs were obtained weekly to monitor the distraction progress. After the desired limb-length had been achieved, distal interlocking screws were inserted and the external fixator was removed. It was important to insert these distal locking screws before removing the fixator to prevent loss of length. After radiographs showed remodeling of two cortices, full weight-bearing was permitted. After completion of bone remodeling, the intramedullary nail was removed at the patient's request.

Control group

The group of patients who had undergone lengthening over an intramedullary nail were retrospectively compared with an earlier group of patients treated with conventional tibial lengthening using an external fixator alone (control group) (Table 1). The patients in the control group had been operated on by the same surgeon who performed the lengthening over an intramedullary nail. The control group consisted of 16 patients and 17 tibias. The mean duration of follow-up for controls was 4.0 years (range 1.1–10.2 years), and their mean age at the time of operation was 14.6 years (range 4–35 years). Six patients were female, and ten were male. Fifteen control patients underwent lengthening because of a limb-length discrepancy, and the sixteenth patient was treated for short stature. The Ilizarov external fixator was used in seven tibias and the Orthofix external fixator in ten. The osteotomy was located in the proximal tibia in all cases.

In both groups we excluded patients who had a history of previous bone infection, open fracture, immature bone, soft tissue compromise, antineoplastic chemotherapy, or bone deformity of a severity that required gradual deformity correction. We also did not include cases treated with bone transport,[19] acute shortening-distraction, or double-level lengthening. In a previous study, we examined the relation between maturation, external fixation indices, and amount of bone lengthening. We concluded that the fixation indices were not valid in cases where lengthening was less than 3 cm.[20] We therefore excluded cases with lengthening of less than 3 cm.

We used three indices to evaluate results in the present study: the distraction index, the consolidation index, and the external fixation index. The distraction index was obtained by dividing the duration of lengthening by the length gained; the consolidation index was calculated by dividing the duration of consolidation (measured from application of external fixation to radiographic consolidation of regenerated bone) by the length gained; and the external fixation index was defined as the entire duration of external fixation divided by the length gained (Fig. 2). We considered consolidation complete when anteroposterior and lateral radiographs confirmed that three of four cortices of regenerated bone in the distraction gap were intact.[12]

Complications were classified according to the system proposed by Paley:[13] Grade 1 represented problems (difficulties arising during treatment that could be fully resolved nonoperatively); grade 2 represented obstacles (difficulties arising during treatment that could be fully resolved operatively); and grade 3 represented sequelae (temporary or permanent difficulties remaining after completion of treatment).

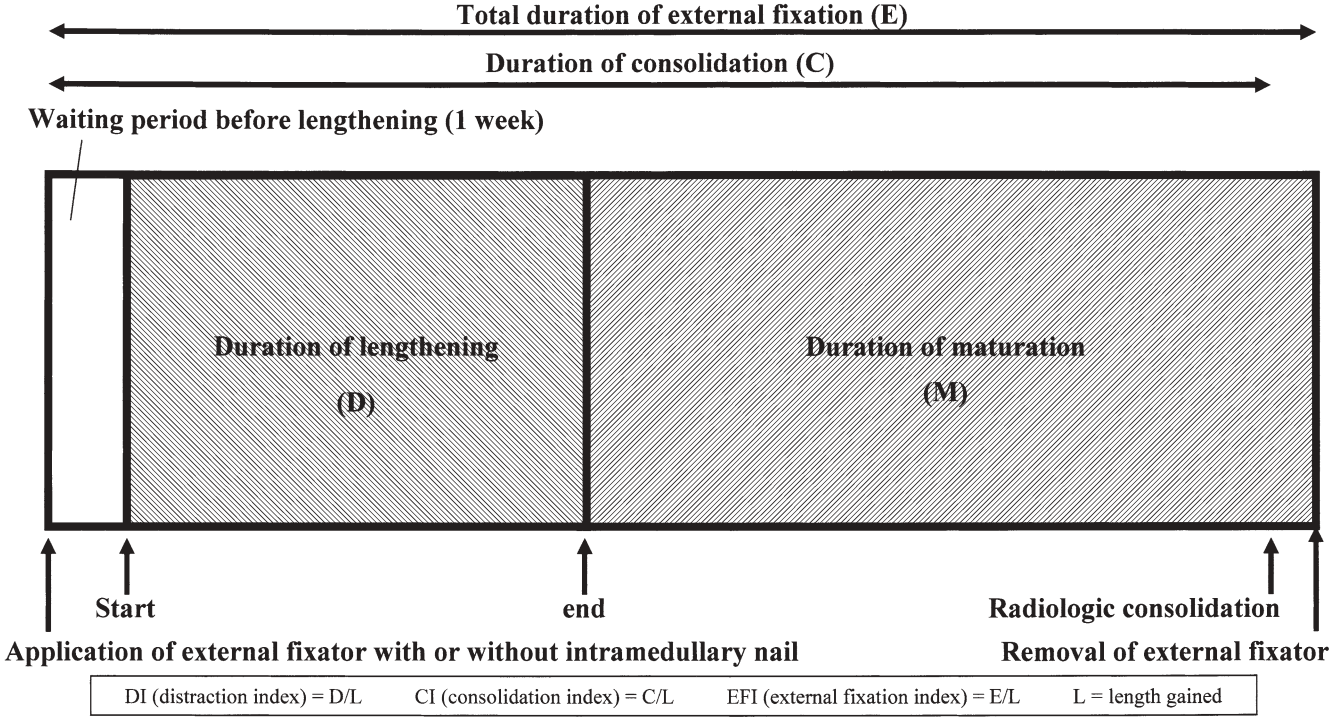

Fig. 2. Course following application of an external fixator (with or without intramedullary nailing) and definitions of related parameters

Statistical significance was evaluated by the unpaired Student's *t*-test. $P < 0.05$ was considered to indicate significance. Mean values are presented ±SD.

Results

The mean age was 22.2 ± 10.3 years (range 14–53 years) in the intramedullary nail (IMN) group and 14.6 ± 7.6 years (range 4–35 years) in the control group, a significant age difference ($P = 0.04$). The reason for this difference was that we did not perform lengthening over an intramedullary nail in patients who were skeletally immature, resulting in a significantly younger control group population. The mean amount of lengthening was significantly greater in the IMN group ($P = 0.01$): 6.8 ± 1.7 cm (range 3.7–8.5 cm) in the IMN group versus 5.0 ± 2.0 cm (range 3.0–9.6 cm) in the control group (Table 2). The mean distraction index did not significantly differ between the two groups: 14.9 ± 2.9 days/cm (range 10.4–19.8 days/cm) in the IMN group versus 13.8 ± 5.9 days/cm (range 7.1–34.7 days/cm) in the control group ($P = 0.51$). The mean external fixation index was significantly lower in the IMN group ($P < 0.001$): 18.0 ± 2.7 days/cm (range 13.5–22.2 days/cm) in the IMN group versus 41.2 ± 17.3 days/cm (range 22.2–73.1 days/cm) in the control group. The mean consolidation index was 45.1 ± 13.7 days/cm (range 31.1–75.4 days/cm) in the IMN group versus 41.0 ± 17.6 days/cm (range 18.5–73.1 days/cm) in the control group (no significant difference; $P = 0.48$). The mean operating time for the IMN group was approximately 1 h longer for the IMN group: 176 ± 48 min (range 98–230 min) versus 121 ± 40 min (range 90–240 min) for the control group. This 1 h difference is comparable to the average operating time for treating a tibial fracture by intramedullary nailing. The mean blood loss recorded in the anesthesia operative record was 55.2 ± 65.1 ml (range 15–330 ml) in the IMN group versus 30.9 ± 44.8 ml (range 15–190 ml) in the control group (no significant difference; $P = 0.24$). We used an air tourniquet during the operation in both groups. No patient required blood transfusion intraoperatively or postoperatively in either group.

Table 2. Results of procedures

Parameter	IMN group	Control group	*P*
LG (cm)	6.8 ± 1.7	5.0 ± 2.0	0.01
DI (days/cm)	14.9 ± 2.9	13.8 ± 5.9	0.51
EFI (days/cm)	18.0 ± 2.7	41.2 ± 17.3	<0.001
CI (days/cm)	45.1 ± 13.7	41.0 ± 17.6	0.48
OT (min)	176 ± 48	121 ± 40	<0.05
BL (ml)	55.2 ± 65.0	30.9 ± 44.8	0.24

LG, length gained; DI, distraction index; EFI, external fixation index; CI, consolidation index; OT, operating time; BL, blood loss
Results are presented as the mean ± SD

Table 3. Occurrence of problems, obstacles, and sequelae in IMN and control groups

Complication	IMN group				Control group			
	Total no.	Severity			Total no.	Severity		
		Problems	Obstacles	Sequelae		Problems	Obstacles	Sequelae
Pin-tract infection	1	0	1	0	10	7	3	0
Deep intramedullary infection	0	0	0	0	0	0	0	0
Axial deviation	0	0	0	0	2	0	2	0
Refracture	0	0	0	0	2	0	0	2
Joint contracture	6	4	2	0	5	2	1	2
Difficulty with intramedullary nail	2	0	2	0	0	0	0	0
Premature consolidation	0	0	0	0	2	0	2	0
Delayed consolidation	0	0	0	0	2	1	1	0
Nerve injury	0	0	0	0	1	0	0	1
Total	9	4	5	0	24	10	9	5

Problems, resolving with medical treatment; Obstacles, resolving with operative treatment; Sequelae, continuing or permanent persistence after treatment

Lengthening over an intramedullary nail was associated with a total of nine complications, including four problems, five obstacles, and no sequelae. The control group had a total of 24 complications, including 10 problems, 9 obstacles, and 5 sequelae (Table 3). Pin-tract infection occurred at only one site in the IMN group, compared with nine sites in the control group, a difference that we attributed to the shorter duration of external fixation in the IMN group. Deep intramedullary infection did not occur in either group. Six joint contractures occurred in the IMN group, with four joints attaining full recovery nonoperatively. One patient required bilateral lengthening of the Achilles tendon. Five joint contractures occurred in the control group: Two fully recovered nonoperatively; one patient required lengthening of the Achilles tendon at one joint; and two contractures were permanent. Two delayed consolidations were also noted in the control group: One was treated by low-intensity pulsed ultrasound,[21] and the other was treated with cancellous bone grafting. No cases of delayed consolidation occurred in the IMN group. Even though we intraoperatively tested the ability of the osteotomy site to separate, premature consolidation occurred in both tibias of one patient who underwent bilateral lengthening without an intramedullary nail. Axial deviation during lengthening occurred in two tibias in the control group, for which we performed deformity correction. No deformity occurred during lengthening in the IMN group. Two control patients suffered refractures compared with none in the IMN group. Two difficulties were associated with the use of an intramedullary nail: breakage of the nail in one case and protrusion of the top of the nail in a second case.

Discussion

We have applied an external fixator over an intramedullary nail in cases of simple tibial lengthening with the aim of reducing the external fixation time. Long-term application of an external fixator is associated with many complications, such as loss of motion at the knee or ankle (or both) and pin-tract infection, as well as interference with activities of daily living. By reducing the duration of external fixation, this combined strategy allows a patient to exercise knee and ankle joints earlier, improves day-to-day functioning, and minimizes complications. Furthermore, this procedure secures axial alignment, maintains length gained, and prevents refracture after external fixator removal.

Our results showed a low complication rate in the IMN group compared with the control group. The overall complication rates in the IMN group and the control group were 0.69 and 1.41 per segment, respectively. In association with the earlier release of IMN patients from external fixation, only one pin-track infection occurred in the IMN group compared with nine in the control group. Generally, the longer the duration of the lengthening is, the worse the joint contracture becomes. In this study, even though the duration of lengthening was significantly longer in the IMN group than in the control group, all patients in the IMN group recovered their preoperative range of motion, whereas two patients in the control group did not fully recover. We believe that the earlier release of the IMN patients from external fixation enabled them all to exercise their ankle joints fully before their joint contractures became irreversible.

Disadvantages of lengthening over an intramedullary nail include the risk of fat embolism, an increased risk of blood loss, disturbance of intramedullary circulation,

and the greater likelihood that pin-tract infections will lead to deep intramedullary infections. Indications for this method are also more limited than for the simple use of an external fixator. Fat embolism is a major concern of combined intramedullary nailing and external fixation, especially with simultaneous bilateral procedures. To prevent this complication, we drilled multiple wire-holes at the planned osteotomy site before reaming and decompressing the medullary canal.[15] In our series, even though five of eight patients had simultaneous bilateral procedures, no patient suffered a fat embolism. Although an intramedullary nail may impede endosteal blood flow, the periosteum and surrounding soft tissue still can support osteogenic cells to permit new bone formation.[15,16,22,23] Kojimoto et al. demonstrated directly in a rabbit model that the periosteum played a more important role in regenerating distraction-callus than did the endosteum.[24] We think that preservation of periosteal function was the reason the CI did not differ significantly between the two groups in our study. As for deep infection, Paley et al. recommended avoiding contact between the pins of the external fixator and the intramedullary nail.[15] We observed this precaution, and no patient developed a deep intramedullary infection. Because Simpson et al.[16] reported a high rate of intramedullary infection in cases of lengthening over an intramedullary nail following open fractures, we considered previous open fracture to be a contraindication for lengthening over an intramedullary nail. As mentioned earlier, bone maturity and other factors also must be considered.

Conclusions

Lengthening over an intramedullary nail produces callus formation of a quality equal to that obtained by the conventional Ilizarov method of lengthening. When performed in suitable cases, as described above, this combined method has a lower complication rate than the conventional method and reduces the burden on the patient that results from long-term external fixation.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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