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Management of Stiff Hypertrophic Nonunions by Distraction Osteogenesis: A Report of 16 Cases

[Original Articles]

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Abstract

Objective: Hypertrophic nonunions can be managed successfully with distraction. Hypertrophic changes indicate that the tissue at the nonunion site has a biologic healing potential. The missing component is an appropriate mechanical environment to transform a hypertrophic nonunion into solid bone.

Design: At our institution, the records of 10 male and 6 female patients treated for stiff hypertrophic nonunion with the Ilizarov distraction method were retrospectively analyzed. The average age of the patients was 42.3 years (range 15–69 years). The nonunion time ranged from 8–48 months. All patients had at least 1 cm shortening, 3 patients had a deformity in one plane, and 13 had a deformity in two planes. The pathology was localized to the upper extremity in 5 patients, to the lower extremity in 11 patients, with a periarticular localization in 11 patients. An Ilizarov-type circular external fixator was applied in all patients to correct shortening, to correct deformity, and to achieve a solid union.

Results: All nonunions healed at an average follow-up of 38.1 months (range 24–95 months). The average time spent in the external fixator was 7.1 months (range 5–10 months). The average preoperative length discrepancy was 2.25 cm (range 1–8 cm), which was eliminated in all patients at the time of frame removal. The average coronal plane angulation of 19.7° (range 15–37°) and sagittal plane angulation of 20.8° (range 5–45°), together with translation in one patient, also were corrected to normal anatomic alignment. Complications included minor pin tract infections and hardware problems; recurrence of deformity was observed in one patient who refused to wear a protective brace after frame removal.

Conclusions: Hypertrophic nonunions can be managed successfully with distraction. The Ilizarov device can address every aspect of a stiff hypertrophic nonunion, including shortening and deformity.

Hypertrophic nonunions usually result from insufficient fracture stabilization. The nonunion tissue and the environment are well vascularized, but the biologic process to union is inhibited by lack of stability. [1–3] The fibrocartilaginous tissue in the nonunion site has an osteogenic potential that is realized when torsional, axial, and shearing instabilities are eliminated by establishment of a stable osteosynthesis construct. [4] Usually, compression is necessary for the healing of a hypertrophic nonunion; however, distraction can aid healing as well when a mechanically stable setting is established. The additional benefit of using distraction is that limb deformity and shortening can be corrected at the same time. [1,5]

If the hypertrophic nonunion is stiff in nature, uniplanar and biplanar fixators cannot provide the stability necessary for distraction. Ring fixators can overcome this inadequacy, however. [5,6] We report the result of callus distraction by the Ilizarov device in 16 patients with stiff, hypertrophic nonunion.

PATIENTS AND METHODS

The current series consists of a retrospective review of 10 male and 6 female patients treated for stiff hypertrophic nonunion with the Ilizarov distraction device at our institutions. The average age of the patients was 42.3 years (range 15–69 years). The nonunion time ranged from 8 (case 1) to 48 (case 2) months. Four patients were previously managed only by cast immobilization, 2 had sequelae of high tibial osteotomies performed with the Ilizarov device, and 10 were operated on at least one time for fracture fixation by internal and/or external fixation (Table 1).

Case No.	Sex	Age (yr)	Bone	Duration Nonunion (mo)	Previous Therapy	Infection (pre)	Infection (post)	ROM (per)	ROM (post)
1	M	28	Radius (diaphysis)	8	Case immobilization	−	−	F/E 130–50 Sup10	F/E 170–30 Sup 40
2	M	42	Tibia (distal)	48	External fixation (×3)	+	−	DF/PF 0–10	DF/PF 15–30
3	M	26	Tibia (diaphysis)	18	Open reduction, internal fixation (×2)	−	−	F/E 130–0	F/E 140–0
4	F	23	Femur (distal)	13	Open reduction, internal fixation	−	−	F/E 100–30	F/E 140–0
5	M	24	Radius (distal)	10	Cast immobilization	−	−	DF/PF 10–10	DF/PF 20–35
6	F	34	Humerus (distal)	9	Cast immobilization	−	−	F/E 90–30 Sup 10	F/E 110–20 Sup 45
7	F	52	Tibia (distal)	14	External fixation (×1)	−	−	DF/PF 10–10	DF/PF 20–30
8	F	50	Tibia (distal)	14	Open reduction, internal fixation (×2)	+	−	DF/PF 5–10	DF/PF 5–40

Case No.	LLD (pre) (cm)	LLD (post) (cm)	Angulation (pre) (%)	Angulation (post) (%)	Fixator Duration (mo)	Bone Healing Index (Fixator Duration/ Length Gained)	Complications	Follow-Up (mo)
1	1	0	F 25	F 0	5	5	None	95
2	2	0	F 15	F 0	10	5	Minor pin tract	24
3	8	0	F 20 S 30 R 51.1	F 0 S 3 R 5.1	6	<1	Relapse of deformity after early frame removal	26
4	5	0	F 32	F 0	10	2	None	31
5	2	0	F 25 S 20 R 37.2	F 2 S 0 R 3.5	9	4.5	None	25
6	1	0	F 37 S 20 R 41.5	F 3 S 1 R 43	8	8	None	30
7	1	0	F 10 S 40 R 43.3	F 0 S 0	7	7	None	45
8	1	0	F 15 S 20 R 22.4	F 0 S 0	5	5	None	42

TABLE 1. Demographic data of the patient groupM, male; F, female; ROM, range of motion; LLD, leg-length discrepancy; F/E, flexion/extension; Sup, supination; F, frontal plane; S, sagittal plane; R, magnitude of real deformity.

Case No.	Sex	Age (yr)	Bone	Duration Nonunion (mo)	Previous Therapy	Infection (pre)	Infection (post)	ROM (per)	ROM (post)
9	F	69	Femur (distal)	12	Open reduction, internal fixation (×1)	–	–	F/E 30–0	F/E 40–0
10	F	40	Tibia (proximal)	11	Cast immobilization	–	–	F/E 95–0	F/E 110–0
11	M	54	Tibia (proximal)	10	High tibial osteotomy with Ilizarov device	–	–	F/E 110–0	F/E 130–0
12	M	15	Tibia (proximal)	11	High tibial osteotomy with Ilizarov device	–	–	F/E 130–0	F/E 120–0
13	M	53	Humerus (distal)	22	Open reduction, internal fixation (×2)	–	–	F/E 90–30 Sup 10	F/E 90–20 Sup 20
14	M	36	Humerus (distal)	10	Open reduction, internal fixation (×1)	–	–	F/E 90–30 Sup 10	F/E 90–10 Sup 25
15	M	50	Femur (proximal)	11	Open reduction, internal fixation (×1)	–	–	F/E 90–20	FE 110–10
16	M	51	Femur (proximal)	14	Open reduction, internal fixation (×1)	–	–	F/E 80–20	FE 110–10

Case No.	LLD (pre) (cm)	LLD (post) (cm)	Angulation (pre) (%)	Angulation (post) (%)	Fixator Duration (mo)	Bone Healing Index (Fixator Duration/ Length Gained)	Complications	Follow-Up (mo)
9	3	0	F 14	F 0	8	2.7	K-wire breakage	54
10	1	0	F 10 S 10 R 16.2	F 0 S 0	8	8	None	39
11	2	1	M 1 cm S 20	M 0 cm S 5	5.5	10	Grade III pin tract infection half-pin removal	44
12	1	0	S 30	S 0	10	10	None	38
13	2	0	F 15 S 15 R 22.3	F 0 S 0	8	4	None	34
14	1	0	F 20 S 5 R 24.8	F 0 S 2 R 3.1	7	7	None	37
15	2	0	F 20 S 5 R 24.8	F 2 S 0 R 3.1	8	4	Minor pin tract	41
16	3	0	F 30 S 10 R 37.2	F 0 S 0	9	3	Minor pin tract	50

M, male; F, female; ROM, range of motion; LLD, leg-length discrepancy; F/E, flexion/extension; Sup, supination; F, frontal plane; S, sagittal plane; R, magnitude of real deformity.

TABLE 1. ContinuedM, male; F, female; ROM, range of motion; LLD, leg-length discrepancy; F/E, flexion/extension; Sup, supination; F, frontal plane; S, sagittal plane; R, magnitude of real deformity.

Two patients (cases 2 and 8) had a history of an active, draining infection at the nonunion site. They did not have draining fistulae and displayed normal C-reactive protein and erythrocyte sedimentation rate levels at the time of admission to our institute. These two patients showed no pathologic findings in indium-111-labeled leukocyte bone scans.

All patients had at least 1 cm shortening, 3 patients had a deformity in one plane, and 13 had a deformity in two planes. The true angle of deformity was calculated according to the oblique plane formula developed by Paley. 7 The pathology was localized to the upper extremity in 5 patients, to the lower extremity in 11 patients, with a periarticular localization in 11 patients (Table 1).

All patients were examined for mobility of the nonunion site under general anesthesia using fluoroscopy. When hardware from previous surgery was present, it was removed using a minimally invasive technique under fluoroscopic control. If the pathology was localized to the tibia, a fibula osteotomy was performed. To be accepted as hypertrophic and stiff, the nonunion had to display a mobility less than 5° in the coronal and sagittal planes, either clinically if no hardware was present or under anesthesia after hardware removal and fibula osteotomy. [8]

In our infected cases, the hardware had been removed in earlier surgeries. In these patients, the nonunion sites were not débrided, but cultures were obtained by tru-cut biopsies of the nonunion site. Culture-sensitive antibiotic therapy was started in the operating room and was continued for 3 weeks, as described by Paley et al [3] and Catagni et al. [5]

The Ilizarov apparatus consisted of a stable three- or four-ring frame. The rings were fixed to the bone using Kirschner wires (1.8 mm diameter) and half-pins (6 and 5 mm diameter). The rings were applied perpendicular to the long axis of the proximal and distal segments of the nonunion. Hinges were adjusted to be in the bisector line and at the convex site of the deformity. The bisector line is the line that divides the true angle of deformity into two equal halves. [7] If hinges are placed on the bisector line and on the convex side of deformity, correction and lengthening are achieved simultaneously. [7] The hinges in our patients were not in neutral positions because all patients had some amount of shortening, and the aim was to correct deformity and length discrepancy while achieving bony union. In periarticular nonunions, the construct was tested for stability using fluoroscopy, and as a result, the neighboring joint was not incorporated into the frame in any patient. No bone graft was used in any patient.

Slow distraction, adjusted to be at a rate of 0.25 mm/day at the apex of deformity and divided in four equal increments, was started at the first postoperative day. Epidural anesthesia was performed in all patients for postoperative analgesia, and rehabilitation was initiated on the first postoperative day. The patients were allowed full weight bearing immediately. The amount of lengthening, angular correction, and quality of regenerated bone were examined radiologically during follow-up visits. Distraction was discontinued when the desired amount of angular correction and lengthening was achieved. The patient was kept in the fixator for an additional period to achieve sufficient consolidation of the regenerated bone, until three cortices were united on anteroposterior and lateral x-rays. Compression was not applied during this period in any patient. After frame removal, the operation site was protected in a brace for 4–6 weeks. Figure 1 shows a patient (case 4) treated with these principles.

FIGURE 1. Patient 4, a 23-year-old woman with hypertrophic nonunion of the distal femur, with a history of 1 previous open reduction and internal fixation and 13-month duration of nonunion. A, Preoperative anteroposterior orthoradiograph. B, Preoperative clinical picture, displaying the deformity and leg-length discrepancy. C, Callus formation during distraction with the Ilizarov device. D, Postoperative anteroposterior orthoradiograph 3 months after frame removal. E, Postoperative clinical pictures show the corrected deformity, leg-length discrepancy, and knee flexion.

RESULTS

Patients were examined with standing anteroposterior and lateral orthoradiographs preoperatively and postoperatively. Leg-length discrepancy and malalignments were determined on these x-rays. All nonunions healed. Patients were followed for an average of 38.1 months (range 24–95 months). The average time spent in the external fixator was 7.1 months (range 5–10 months). The average preoperative length discrepancy was 2.25 cm (range 1–8 cm), which was eliminated in all patients at the time of frame removal. The average coronal plane angulation of 19.7° (range 15–37°) and sagittal plane angulation of 20.8° (range 5–45°), together with translation in one patient, also were corrected to physiologic levels (Table 1). Infection resolved spontaneously in both patients (cases 2 and 8).

Complications usually were treated easily and without any sequelae. A minor pin tract infection developed in three patients (cases 2, 15, and 16). These infections resolved with meticulous local pin site care and oral antibiotics. A grade III infection in case 11 required removal of one of the 6-mm half-pins in the upper segment and débridement of the pin site, and a new half-pin was inserted at a different level. A K-wire breakage (case 9) was neglected because there were four other beaded K-wires securing the same segment. In patient 3, the frame was removed at the sixth postoperative month, and the patient refused to wear a protective brace. A deformity recurred and the regenerated bone collapsed for 3 cm. The patient was operated on again with an Ilizarov device according to the same protocol, the recurred angulation and shortening were corrected, and the frame was kept until all four cortices were healed on x-rays (Table 1).

DISCUSSION

Basic principles of the treatment of nonunions are reported in the literature. [8,9] Previously, compression at the nonunion site was believed to enhance healing, and distraction was thought to be a predisposition for nonunion. [10] Ilizarov [11] stated that callus can proliferate, if mechanical and biologic stability plus vascularity of the nonunion site is provided. Hypertrophic changes at a nonunion site confirm the biologic capacity of the bone-forming cell. All that is absent is mechanical stability, which, if established, allows the elements at the nonunion site to promote callus formation. [2,11]

In periarticular and metaphyseal nonunions particularly, ring fixators provide superior stability compared with unilateral fixators. [6] In addition, stiff nonunions do not allow acute, anatomic correction of the deformity, so a closed intramedullary nailing is not possible. [1] In the current series, all patients demonstrated a stiff deformity that did not allow for a closed intramedullary nailing. The invasive nature of open plating may threaten the vascularity surrounding the nonunion. [1] All of the inadequacies of unilateral fixators, intramedullary nailing, and plate and screw osteosynthesis can be addressed by ring fixators.

No débridements were done in patients with a previous history of osteomyelitis and no active fistula at the time of the index operation, as described by Catagni at al. [5] Ilizarov [11] noted that nonunions complicated by chronic bone sepsis can be treated by compression and/or distraction. The increased vascularity promotes healing of the infection. Small sequestra also become assimilated in the process of active osteogenesis. [11]

Paley et al [3] reported a series of 25 tibial nonunions with bone loss, including three cases of distraction of hypertrophic nonunions. They further categorized nonunions into stiff, partially mobile, and flail types. [12] According to their classification, stiff nonunions have less than 5° motion at the site of the pathology and can be treated by distraction only. [12] In the current series, all patients fit Paley's description of stiff hypertrophic nonunion.

The distraction necessary for callus production can be performed by almost every kind of external fixator. In patients with stiff nonunions, nonunions close to a joint, and malunions with oblique plane deformities, the force needed for stability and distraction can be provided only by circular external fixators. [6,9] We applied the Ilizarov device in all patients of the current series because there were 13 patients with an oblique plane deformity and 11 patients with a periarticular nonunion. Initial stability in patients with periarticular nonunions enabled them to begin range-of-motion exercises at the first postoperative day.

Distraction osteogenesis for the treatment of hypertrophic nonunions has been reported in the literature previously. [1,5,11,13–15] Heiple and Herndon [10] published the first series of cases in which distraction was the modality of treatment of hypertrophic nonunions. Deformities were corrected in all patients, and shortening was corrected in 86% of patients. Saleh and Royston [9] presented a group of posttraumatic hypertrophic nonunions, treated by callus distraction with an external fixator. They calculated a bone-healing index, described as the duration of treatment in months divided by the length gained in centimeters, ranging from 1.5–15 months (mean 5.1 months). The current series includes 16 patients, almost all with an oblique plane deformity, completely treated for shortening and angulation with a mean bone healing index of 5.4 months (range 0.7–10 months) per centimeter, similar to the above-mentioned series. Gordon et al [1] reported a series of three pediatric patients with posttraumatic, rigid, hypertrophic nonunions. They obtained complete bone healing and corrected length discrepancy and deformity by distraction.

A unique group in the current series includes patients with a nonunion after a high tibial ostetomy performed by an Ilizarov device. The two cases healed completely after distraction. Rozbruch et al 8 reported a series of 5 patients with a hypertrophic nonunion after high tibial ostetomy, all of whom they treated by callus distraction.

The current study and others 1,5,11,13–15 indicate that hypertrophic nonunions can be managed successfully with distraction. Hypertrophic changes reveal that the tissue at the site of nonunion has a biologic healing potential. The missing component is an appropriate mechanical environment to induce callus formation. Shearing forces must be neutralized, and a bony realignment should be established, which is provided by a stable external fixator.

In conclusion, the Ilizarov device can address every aspect of a stiff hypertrophic nonunion, including shortening and deformity. It is particularly valuable for periarticular nonunions and avoids many of the disadvantages of other forms of treatment of this problem.

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