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Bifocal Compression-Distraction in the Acute Treatment of Grade III Open Tibia Fractures With Bone and Soft-Tissue Loss: A Report of 24 Cases

[Original Article]

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Abstract

Objective: To evaluate the results of bifocal compression-distraction method for the acute treatment of open tibia fractures with bone and soft-tissue loss.

Design: Patients were selected for bifocal compression-distraction (shortening and lengthening) who had open tibia fractures with bone and soft-tissue loss and a Mangled Extremity Severe Score of 6 and below indicating good leg viability.

Patients: Bifocal compression-distraction osteogenesis using the Ilizarov type circular external fixator was applied to 24 patients with 14 grade IIIA and 10 grade IIIB open tibia fractures with bone and soft-tissue loss. Mean age of the patients was 30.6 years (range 18–53). The mean bone defect was 5 cm (range 3–8.5). The mean soft tissue defect was 2.5 × 3.5 (1 × 2–10 × 5) cm.

Interventions: Acute shortening at the fracture site was done for patients with bone defects up to 3 cm to achieve apposition of bone ends. Gradual shortening at a rate of 2 mm/d was done for patients who had bone defects more than 3 cm. Leg length discrepancy was overcome by lengthening at the same time through a corticotomy at a proximal or distal level depending on fracture localization, until there was equalization of leg lengths.

Results: Mean follow-up period was 30 months (range 18–60). Mean bone healing time was 7.5 months (range 4–11). The mean time in external fixation was 7.1 months (range 3–10), and the average external fixator index was 1.4 months/cm. Results were evaluated using the Paley bone and functional assessment scores. The bone assessment results were excellent in 21 and good in 3 patients. Functional assessment scores were excellent in 19, good in 4, and fair in 1 patient. Pin site infections were present in 10.7% of the pin sites. There were 52 complications in 24 patients, for a complication rate per patient of 2.08. Of the complications, 48.1% were problems (minor complications), 38.5% obstacles (major complications requiring a surgical solution), and 13.4% sequelae (true complications). Minor complications included soft tissue inflammation and infection, translation/angulation, and delayed maturation during distraction and transient knee contracture and loss of motion. All grade 1 and 2 soft tissue inflammations and infections healed with nonoperative therapy. Major complications included pin tract infection and reinfection, equinus deformity, frame failure, and premature consolidation, all of which required additional surgery to correct the problem. Sequelae included leg length discrepancy, loss of knee/ankle range of motion, knee flexion contracture, malalignment, and chronic osteomyelitis.

Conclusion: Bifocal compression-distraction osteogenesis is a safe, reliable, and largely successful method for the acute treatment of open tibia fractures with bone and soft-tissue loss. Further nonoperative or operative treatment can correct most complications.

Treatment of posttraumatic defects of the tibia accompanied by severe soft-tissue injuries in open fractures has continued to be a therapeutic problem for orthopedic surgeons. In the literature, the Papineau technique, vascularized or nonvascularized transfer of fibula, debridement followed by vascularized muscle transfer, and employment of autografts or allografts after osteosynthesis with nails, plates, or external fixators have been reported as treatment alternatives. However, these studies have also stressed a prolonged treatment period and significant complications such as nonunion, shortening, deformities, and infections during the treatment period. [1–12] Higher rates of nonunion and infection are apparently observed in open fractures. [5,6,10,13,14] The method of distraction osteogenesis, first introduced by Ilizarov [15] and later popularized by the surgeons in the West, has revolutionized the management of tibia fractures with bone defects [1,13,14,16–24] (Table 1).

Inspired by Ilizarov's philosophy, management of open tibia fractures with bone and soft tissue defects can be accomplished by acute shortening of the fractured area and lengthening of the bone at another level. Distraction osteogenesis following acute shortening using an Ilizarov type circular fixator not only establishes union but also compensates for the length discrepancy by employing distraction at the same time, thus achieving reorientation and realignment of the extremity.

Authors (year)	Case No.	Mean Bone Loss (cm)	Duration Treatment (mos)	Success Rate (%)	No. Additional Surgeries per Patient
Catteneo et al[16] (1992)	28	4	9	75	0.6
Cierny and Zorn[29] (1994)	21	6.5	17	71	1.4
Green et al[31] (1992)	17	5.14	9.6	94	3.5
Marsh et al[17] (1994)	25	4.1	8.5	80	2.1
Polyzois et al[21] (1997)	25	6	10	90	—
Saleh and Rees[22] (1995)	8	6.5	16	100	2.2
Song et al[24] (1998)	27	8.3	8	81	0.5
Paley and Maar[20] (2000)	19	10	16	95	2.9

—, not applicable.

TABLE 1. Results of Bone Transport for Bone Loss

The purpose of this study is to evaluate the results of bifocal compression-distraction osteogenesis by the Ilizarov external fixator, applied acutely for open tibia fractures with bone and soft tissue loss.

MATERIALS AND METHODS

Between January 1997 and June 1999, 143 patients with open and closed fractures of the tibia were treated surgically at our institution. Twenty-four patients (18 male, 6 female) who had open tibia fractures with bone and soft-tissue loss were managed by bifocal compression-distraction osteogenesis using an Ilizarov external fixator. Only patients with a Mangled Extremity Severe Score (MESS) 25 6 and below (good lower leg viability) and a bone defect were included in the study. Patients who had poor lower leg viability with an MESS score over 6 and patients with noncomminuted fractures were excluded. Fractures were caused by car accidents in 17, industrial injuries in 4, and falling from heights in 3 patients. Patients with multiple injuries were excluded. The mean age of the patients was 30.6 years (range 18–53). All soft tissue defects were measured; their mean size was 2.5 × 3.5 cm (range 1 × 2–10 × 5). All of the soft tissue wounds were in the anterolateral or anteromedial aspect of the tibia. Exposed bone with periosteal stripping was present in 10 patients. Mean bone defect was 5 cm (range 3–8.5). Using the Gustilo-

Andersen classification, there were 14 grade IIIA and 10 grade IIIB open fractures. The fractures were also classified according to the AO/ASIF system (Table 2). No patients in this series had a neurovascular deficit. The surgeons involved in the care of these patients routinely perform 300 external fixations yearly.

Case No.	Age (yrs)	Fracture Type (AO)	Gustilo-Andersen	Bone Loss (cm)	Soft-Tissue Loss (cm)	Follow-up (mo)	Bone Healing Time (mo)	Length of External Fixator Wear (mo)
1	28	B3	Stage IIIA	4	3 × 4	24	8	6
2	46	C2	Stage IIIB	3	3 × 2	24	5	3
3	34	B3	Stage IIIA	5	1 × 2	34	9	7
4	37	C2	Stage IIIA	5	4 × 8	24	7	6
5	22	B3	Stage IIIB	5	10 × 5	18	7	7
6	28	B3	Stage IIIB	5	3 × 4	38	8	7
7	33	B3	Stage IIIA	6	1 × 3	36	9	8
8	35	C3	Stage IIIA	7	2 × 3	23	10	9
9	18	B3	Stage IIIA	3	2 × 4	54	4	3
10	31	C2	Stage IIIB	6	2 × 3	43	8	8
11	38	C3	Stage IIIB	4	2 × 3	21	6	7
12	37	B3	Stage IIIB	6	3 × 3	27	9	8
13	25	B3	Stage IIIA	5	1 × 2	38	7	7
14	20	C2	Stage IIIA	7	2 × 4	18	11	10
15	21	C2	Stage IIIB	3	3 × 3	30	5	4
16	18	B3	Stage IIIA	4.5	1 × 3	29	7	10
17	53	C3	Stage IIIB	8.5	1 × 4	26	11	8
18	18	B3	Stage IIIA	6	2 × 4	60	8	7
19	30	C2	Stage IIIA	4	1 × 2	20	6	6
20	29	C3	Stage IIIB	4	3 × 6	36	7	10
21	34	C3	Stage IIIA	7	2 × 5	22	10	10
22	32	B3	Stage IIIB	7	3 × 4	26	9	6
23	40	C2	Stage IIIA	3	1 × 2	18	5	8
24	26	C3	Stage IIIA	3.5	3 × 2	33	5	7

Case No.	Radiologic Results				Bone Results		Functional Results	
	MPTA	LDTA	PPTA	ADTA	Final Situation	Grade	Final Situation	Grade
1	87	90	81	78	Union	Excellent	Full ROM	Excellent
2	89	90	81	82	Union (0.5 cm LLD)	Excellent	Full ROM	Excellent
3	86	91	79	80	Union	Excellent	10° knee flexion contracture	Good
4	87	89	77	80	Union	Excellent	Full ROM	Excellent
5	87	89	81	80	Union	Excellent	Full ROM	Excellent
6	88	87	80	79	Union	Excellent	Full ROM	Excellent
7	89	88	80	81	Union (chronic osteomyelitis)	Good	Full ROM	Excellent
8	87	86	80	78	Union (1 cm LLD)	Excellent	Full ROM (brace needs)	Good
9	87	87	78	82	Union	Excellent	Full ROM	Excellent
10	88	91	81	78	Union	Excellent	Full ROM	Excellent
11	88	88	81	81	Union	Excellent	Full ROM	Excellent
12	88	90	81	82	Union	Excellent	Full ROM	Excellent
13	87	90	79	81	Union	Excellent	Full ROM	Excellent
14	87	89	78	80	Union	Excellent	Full ROM	Excellent
15	89	89	80	80	Union	Excellent	Full ROM	Excellent
16	89	90	81	80	Union (10° procurvatum)	Good	20° loss of ankle joint motion	Good
17	86	90	81	79	Union	Excellent	Full ROM	Excellent
18	88	84	80	80	Union	Excellent	20° loss of ankle motion	Good
19	87	88	79	78	Union	Excellent	Full ROM	Excellent
20	87	88	79	81	Union	Excellent	Full ROM	Excellent
21	88	89	80	82	Union	Excellent	Full ROM	Excellent
22	88	89	81	80	Union (3 cm LLD)	Good	Pain and 30° loss of knee joint motion	Fair
23	88	88	80	79	Union	Excellent	Full ROM	Excellent
24	87	90	79	80	Union	Excellent	Full ROM	Excellent

TABLE 2. Patients in This Study

TECHNIQUE

The surgical intervention was performed an average of 8 hours (range 4–26) after injury. Resection of the devitalized bone ends was followed by debridement and irrigation of the wound area with 8 to 10 L of physiologic saline. If the fibula was intact, a resection was carried out between the fracture and osteotomy site, so that the lengthening could be done. A preoperatively constructed Ilizarov frame was used. The proximal reference wire was inserted perpendicular to the mechanical axis of the tibia and was fixed to the most proximal ring. A distal reference wire parallel to the ankle joint was secured to the most distal ring. At this stage, the alignment of the tibia was examined radiographically. The amount of acute shortening was limited by the circulatory status of the foot. Shortening was performed while monitoring the dorsalis pedis and tibialis posterior arteries by Doppler ultrasound, which was continued throughout the entire procedure. If the fracture was very close to the ankle joint, the foot was included into the frame to prevent equinus contracture and to enhance the stability of the osteosynthesis. At this stage, the osteotomy for distraction was performed either by the Gigli saw method or by multiple drill holes and corticotomy. [26] Based on our experience, acute shortening up to 3 cm can be done without complications. In patients with bone defects more than 3 cm, gradual shortening of 2 mm/d postoperatively should be done. Distraction for lengthening is initiated at a rate of 1 mm/d after a latency period of 10 days. Soft tissue defects were closed primarily in 18 cases after acute shortening and as primary delayed closures at the end of gradual shortening in the remaining 6 cases. A single dose of cefazolin (1 g intravenously) was given preoperatively and continued 4 × 1 g intravenously for 48 hours. Systemic oral administration of ciprofloxacin (750 mg 2 times a day) was prescribed for patients who had pin tract infection. Daily cleaning with Betadine solution and a pressure dressing was used for the care of pin sites. Active range of knee and ankle motion and isotonic quadriceps exercise were begun on the first day after surgery. Patients were encouraged to partial weight bearing with crutches on the second day after surgery. Full weight bearing was allowed at the end of the distraction period. Thromboprophylaxis was not administered to any patient. Nonsteroidal anti-inflammatory or narcotic analgesic drugs were not prescribed.

RESULTS

The mean follow-up period was 30 months (range 18–60). Results were evaluated according to the Paley et al classification of bone and functional results. [19] Bone results were assessed based on the status of union, the presence of infection, deformity, shortness of the leg, and mechanical insufficiencies at the union and regenerate site. Functional results included 5 criteria: pain, walking without aids, contractures of the foot, ankle or knee, limited range of motion (ROM) of knee, ankle, and subtalar joint mobility compared with preoperative mobility, and ability to return to normal daily activities and/or work. After fixator removal, patients were encouraged to begin full weight bearing with a protective brace for 1 to 2 months. Radiologic results were evaluated on both anteroposterior and lateral x-rays. We measured the medial proximal tibial angle (MPTA), lateral distal tibial angle (LDTA), posterior proximal tibial angle (PPTA), and anterior distal tibial angle (ADTA) according to Paley et al 27 (Table 3).

Angle	Normal (°)	Range (°)
MPTA	87	85–90
LDTA	89	86–92
PPTA	81	77–84
ADTA	80	78–82

TABLE 3. Diagram for Paley et al's Radiologic Measurements 27

Using the above-mentioned criteria, we obtained excellent results in 21 and good results in 3 patients in terms of bone assessment. Functional results were excellent in 19, good in 4, and fair in 1 patient. All radiologic measurements demonstrated normal alignment and orientation at the last follow-up (Fig. 1), except the patient in case 16, who united with a 10° procurvatum deformity.

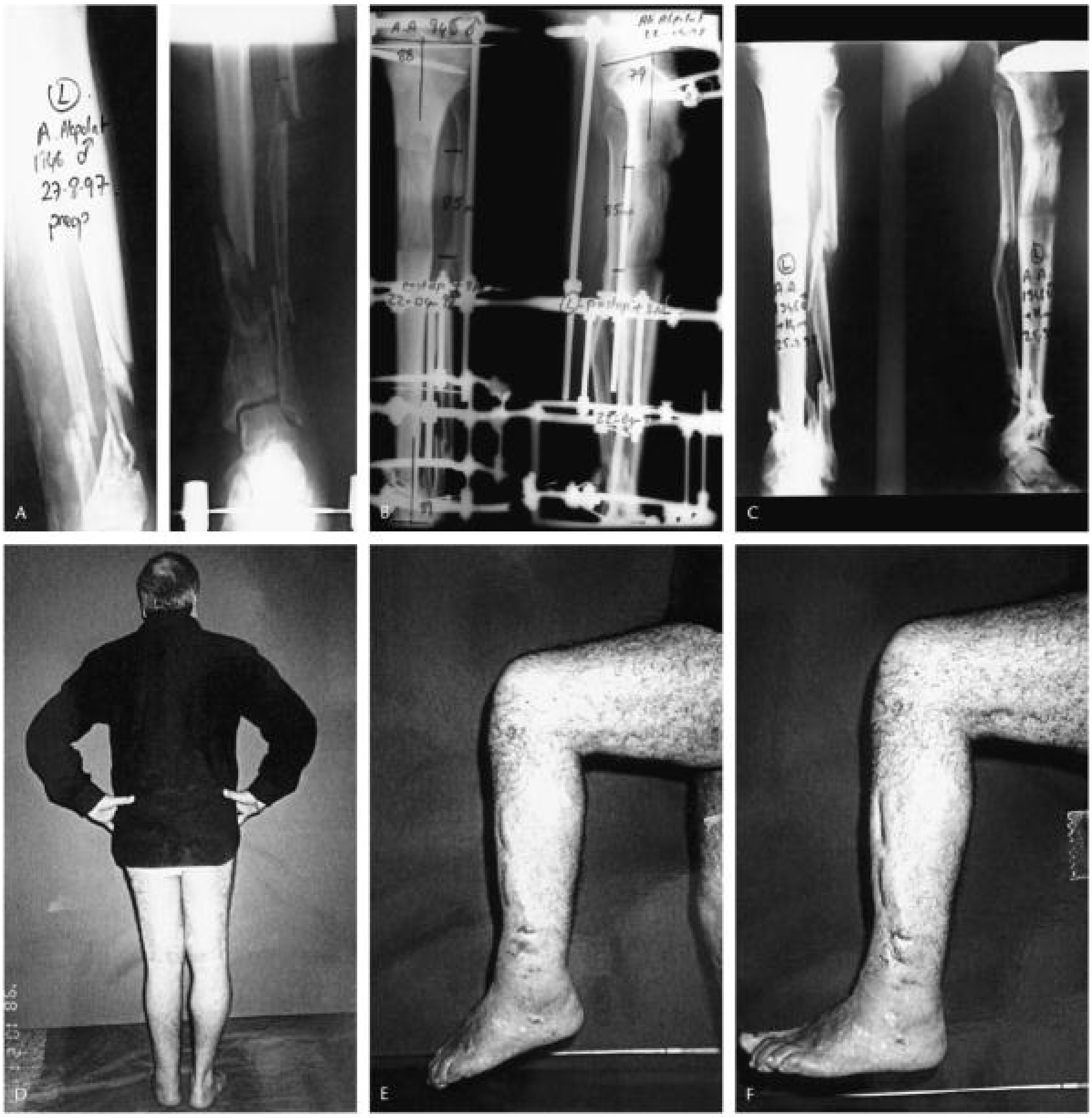

FIGURE 1. 53-year-old male patient (case 17), who sustained a grade IIIB open fracture of his left distal tibia with 8.5 cm. bone loss. A, Preoperative anteroposterior and lateral x-rays. B, Late postoperative x-rays taken at the end of the distraction period. C, X-rays after frame removal displaying complete union of the fracture and completed lengthening through the proximal tibia. D, Leg length equality at the end of treatment. E and F, Ankle ROM during the last follow-up examination.

The average hospitalization time was 5 days (range 3–7). The mean bone healing time was 7.5 months (range 4–11). The average external fixation time was 7.1 months (range 3–10). The mean external fixator index (EFI) was 1.4 months/cm. Complete union was achieved in all patients. Refracture was not observed after removal of the frame. In addition, none of the patients needed primary or secondary bone graft at the docking site. Acute or gradual compression at the fracture site allowed primary closure of all soft tissue defects without the necessity for secondary reconstructive procedures.

All demographic details of our patients are demonstrated in Table 2.

COMPLICATIONS

As seen in Table 4, using Paley's classification, 28 minor complications were listed as problems that did not require additional surgery; major complications were listed as obstacles that resolved with additional surgery, and true complications or sequelae are those complications that remained unresolved at the end of the treatment period. Pain was the most common complaint during the distraction period. This was true in cases requiring lengthening of more than 4 cm, as increasing pain due to dermal irritation caused by wires and screws was encountered; this was relieved by oral analgesics. None of our patients developed neurovascular deficits while in the frame. Similarly, there were no intraoperative neurovascular injuries caused by pin insertion, nor did acute shortening cause any neurovascular problems. Additionally, no compartment syndrome was seen initially or subsequently observed in this series. The most frequent complication seen in our patients was pin tract infection, which was found in 24 (10.7%) pin sites out of a total of 225 pins in 24 patients. Paley used 3 categories for pin site problems 28: grade 1: soft-tissue inflammation; grade 2: soft-tissue infection; and grade 3: bone infection. There were 15 pin tract complications in 11 patients. Eleven grade 1 soft-tissue inflammations were treated by local care using Betadine solution and oral antibiotics (ciprofloxacin 750 mg twice daily), with resolution of the complication at all pin sites. For the 4 grade 2 infections, loose wires were tensioned, local wound care done, and intravenous antibiotic therapy started with resolution of infection at all pin sites. Nine infected wires or pins in 7 patients with grade 3 infections had to be removed and replaced.

Complications	No. Complications	No. Patients	Complication Rate (%)
Problems (minor complication)			
Grade 1 and 2 soft tissue inflammation and infection	15	11	28.9
Translation/angulation at regenerate site (during distraction)	2	2	3.8
Delayed maturation of regenerate site (during distraction)	4	4	7.8
Transient knee flexion contracture	2	2	3.8
Transient loss of ankle motion	2	2	3.8
Total	**25**		**48.1**
Obstacles (major complication and solution)			
Pin tract infection (exchange of pin and wire)	9	7	17.3
Reinfection (irrigation and debridement)	2	2	3.8
Equinus deformity (lengthening of the Achilles tendon)	2	2	3.8
Frame failure (modification of frame)	4	4	7.8
Premature consolidation (recorticotomy)	3	3	5.8
Total	**20**		**38.5**
Sequelae (true complication)			
LLD >2.5 cm	1	1 (case 22)	1.9
Loss of knee-ankle ROM ≥20°	3	3 (cases 16,18,22)	5.8
Knee contracture >5°	1	1 (case 3)	1.9
Malalignment >5°	1	1 (case 16, procurvatum)	1.9
Infection (chronic osteomyelitis)	1	1 (case 7)	1.9
Total	**7**		**13.4**
All complications	**52**		**100**

TABLE 4. Complications Encountered in the Study Group

Regarding sequelae, in 1 patient with a bone defect of 7 cm (case 22), lengthening was discontinued after a painful, severe restriction of knee joint motion. The bone defect was located below the tibial tubercle, and he subsequently lost 30° knee joint motion and was functionally rated as fair. Although the patient had a residual leg length discrepancy (LLD) of 3 cm, his bone result was rated as good.

Patient 7 developed a chronic osteomyelitis but refused any further surgical intervention because of his underlying mental illness. In patients (cases 16 and 18) with >20° loss of ankle joint motion, the bone loss was very close to the ankle joint. In those patients, we shortened the gap acutely and included the foot into the frame during the entire external fixation period.

Patient 3 had an intra-articular extension of his fracture into the knee joint. His final knee ROM included a 10° flexion contracture with a functional rating of good.

Overall, this series had 52 complications in 24 patients for a complication rate per patient of 2.08. We rated complications as minor (problems) in 48.1%, major (obstacles) in 38.5%, and true (sequelae) in 13.4% of the patients. Six of our patients demonstrated no complications.

Complications encountered in our patients are displayed in Table 4.

DISCUSSION

Because open tibia fractures are usually caused by high-energy trauma, they are frequently associated with soft-tissue loss. Commonly, multiple operations are required to close the soft-tissue defect and accomplish bony union. During the treatment period, infection leading to osteomyelitis, bone deformities, malalignment, and shortening of the extremity can be encountered. [1,3–12]

Besides the classic osteosynthesis method, one of the popular alternatives for the treatment of open tibia fractures with soft tissue defects is the transfer of free muscle flaps and the application of intramedullary nails. [4,5,10] However, the incidence of additional interventions to achieve bone union is high and can be complicated by severe infection. In a series of 33 cases treated with local or free muscle flaps and unreamed intramedullary nails, Shephard et al [10] reported infection and revision rates to be 15% and 42%, respectively. In their series of 84 patients with Gustilo IIIB and IIIC fractures, Gopal et al [5] found the rates of superficial and deep infections to be 6% and 9.5%, respectively, which necessitated additional surgical procedures in one-third of the patients.

Although amputation may be an alternative treatment of severe open tibia fractures, young and active patients should be considered candidates for limb salvage procedures. Our patient group had a mean age of 30.6, a MESS score 6 and below, and all of them had open fractures with bone and soft tissue loss. However, none had any risk factors for amputation.

The presence of soft-tissue loss associated with a bone defect complicates treatment. Reconstructive techniques such as skin grafts, rotation flaps, and free flaps have been recommended as procedures for the soft tissue loss. [4,5,6,7,8,10,23] However, these further surgeries can increase hospitalization time, costs, and morbidity. In contrast, acute shortening at the fracture site facilitates wound closure and compensates for bone loss simultaneously. It also allows for the expected advantages of shortening hospitalization time and decreasing morbidity and costs. In our series, all patients demonstrated soft-tissue loss. All wounds healed completely after acute or gradual shortening without the requirement for secondary soft-tissue surgery. Moreover, because our patients were discharged within 1 week's time, the cost of hospitalization was less when compared with traditional treatment methods. [5–8,10,23,29]

An alternative method to provide solid union is to compensate for bone loss by transporting healthy bone to the fracture site, hence bridging the bone defect. At the same time, morbidities such as LLD, malalignment and malorientation, joint contracture, and infection are corrected as accurately as possible. The bone transport technique was reported initially as distraction ostegenesis by Ilizarov [15] and then popularized and widely used by orthopaedic surgeons in the West to reduce or prevent all of the above-mentioned complications. However, this method has also disadvantages, the most prominent being a prolonged external fixation period. Additionally, complications can occur both at the docking and regenerate sites. [1,2,13,14,17–24,30,31]

Alternative methods have been investigated, aiming for union by compensation of bone loss as quickly as possible and correction of malalignment and LLD at the same time. In this context, bifocal compression-distraction osteogenesis using an external circular fixator has been reported by Giebel [32] and later Salis de Gauzag et al, [33] who recommended acute shortening with subsequent lengthening and presented a case report. Saleh et al [34] reported that soft tissue and bone defects following high-energy traumas could be managed by acute shortening, resulting in less morbidity and eliminating the need for bone grafting. In another study, Saleh and Rees [22] compared 8 patients managed by bone transport with 8 cases of bifocal compression-distraction osteogenesis in tibial nonunions with bone loss. The mean duration of treatment was found to be 16 months and 9.8 months, respectively.

In a study by Cierny and Zorn, [29] the EFI was calculated as 1.6 months/cm for a mean bone loss of 6.4 cm. Dagher and Roukoz [30] reported an EFI of 1.8 months/cm for a mean bone defect of 6.3 cm. Green et al [31] found an EFI of 1.9 months/cm for a mean bone defect of 5 cm. In a study conducted by Paley and Maar, [20] mean EFIs for a mean bone loss of 10.7 cm were reported to be 2.1 months/cm in a single-level bone transport and 1.2 months/cm in a double-level bone transport. Saleh and Rees [22] reported an EFI of 2.04 months/cm for a mean bone defect of 4.7 cm in the bifocal compression-distraction group associated with acute shortening, whereas in the bone transport group, the EFI was 2.5 months/cm for a mean bone defect of 6.5 cm.

Cierny and Zorn, [29] Green et al, [31] Marsh et al, [17] and Paley and Maar [20] reported complication rates per patient for their bone transport groups as 1.4, 3.5, 2.1, and 2.9, respectively.

Saleh and Rees [22] reported that complication rates per patient were 1.0 in the compression-distraction group and 2.2 in the bone transport group.

In our study group consisting of 24 patients, the EFI was 1.4 months/cm, and we observed a total of 52 complications in 24 patients for an incidence per patient of 2.08. Moreover, the rate of problems was 48.1%, the rate of additional surgery due to obstacles was 38.5%, and the rate of sequelae was 13.4% in our study group. These findings support the argument that, when compared with bone transport series and length of external fixation, the treatment period was shortened and the rates of complications and secondary interventions were decreased in patients who underwent simultaneous acute shortening and lengthening. We believe that our lower complication rate can be attributed to the minimization of docking site problems. Because bone ends lose their viability and their potential for union due to atrophy until apposition occurs, many authors agree that bone grafting must be performed especially in cases of bone transport. [1,18,20,22,24,29,31] On the other hand, in acute shortening, bone ends come easily in apposition during the immediate posttraumatic period when they have maximal viability. This is confirmed by our finding that none of our patients needed bone grafting. Additionally, malalignments such as angulation and translation have frequently been observed in cases treated by bone transport; these morbidities were not encountered in our group of patients, except case 16.

In our study, we achieved union, normal lower extremity alignment, and limb length equalization in all but 3 patients (1 LLD, 1 procurvatum deformity, and 1 chronic osteomyelitis) at the end of treatment. Moreover, we obtained 85% excellent and 15% good results in terms of bone scores and 80% excellent, 15% good, and 5% fair results for functional scores. When external fixation index and complication rates are compared, our results appear to surpass those of bone transport studies. [18,20,22,24,29,31] As compared with other series, it should be noted that in this study, most complications (48.1%) were rated as problems (minor complications) that did not require additional surgery for their treatment.

CONCLUSION

In the acute management of open tibia fractures complicated by bone and soft-tissue loss, bifocal compression-distraction osteogenesis using an external circular fixator is a safe and successful method in certain selected cases. The technique allows for union together with realignment, reorientation, and normal leg length of the extremity. Furthermore, this technique provides for acute/delayed primary closure of the wound, which is a unique feature of this method of acute reconstruction.

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