

# TREATMENT OF TRAUMATIC BONE DEFECTS BY BONE TRANSPORT

C. KESEMENLI, M. SUBASI, T. KIRKGOZ, A. KAPUKAYA, H. ARSLAN

**This study retrospectively evaluates the results of the management using the callus distraction method, of 19 patients who had developed bone defects following acute trauma.**

**Sixteen patients were males, with a mean age of 19.4 years (6-41 years). Thirteen patients developed bone defects as a result of high-velocity gunshot injuries, and six had defects caused by traffic accidents. The location of 12 fractures was the tibia, and seven were in the femur.**

**The mean follow-up period was 23.6 (12-40) months. The mean length of the bone defect was 6.8 cm (4-16 cm), the distraction index was 13.3 days/cm (7.5-18 days/cm) and the external fixation index was 36.6 days/cm (32.5-46 days/cm). Fifteen (9%) pin-tract infections were observed among those who underwent circular external fixation and four (10%) in cases who underwent unilateral external fixation. There were no deep infections. Refracture was noted in one patient (5%), and two (11%) had delayed union at the target site. One patient developed nonunion at the target site.**

**For the treatment of large bone defects, the callus distraction method may be an alternative option to conventional treatment methods.**

**Keywords :** bone defects ; callus distraction.

**Mots-clés :** défaut osseux ; ostéogénese en distraction.

## INTRODUCTION

The treatment of segmental bone defects is a difficult problem. In the past, amputation was the usual treatment for most fractures with segmental bone defects ; however, different treatment methods are now available. Allografts, autografts and vascularized bone grafts are frequently used for the

reconstruction of large segmental bone defects caused by trauma (5). However, these methods have some disadvantages such as inadequate supply of bone grafts, morbidity at the donor site in case autografts are used and nonunion or infection in case allografts are used. Other techniques have therefore been tried, such as bone transport, which was first suggested by Ilizarov. Good bone consolidation can be achieved with this method without need for internal fixation and bone graft (5, 7).

This study evaluates the results of the management of post traumatic segmental bone defects using a method of distraction osteogenesis.

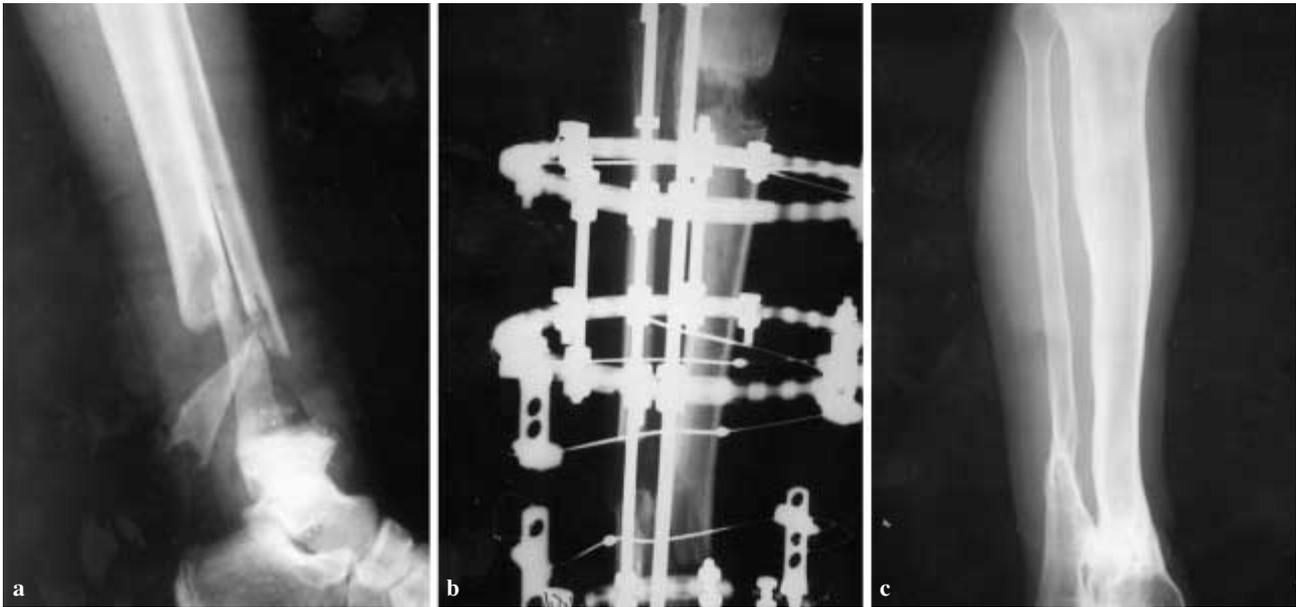
## PATIENTS AND METHOD

The results of the treatment of 19 patients with segmental bone defects following trauma between 1995 and 1999 were evaluated. The patients were 16 males (84%) and 3 females (16%), and their mean age was 19.4 years (6-41 years). The defect developed in 13 patients (68%) as a result of high-velocity gunshot injuries and in 6 patients (32%) as a result of traffic accidents. Twelve fractures were located in the tibia, seven were located in the femur ; 12 were on the right and seven were on the left lower extremity. All patients had Gustilo type 3B open fractures. The patients who had vascular injury were excluded from this study. The patients were operated under emergency conditions. Following irrigation of the wound and debridement of necrotic tissues, the

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Department of Orthopedic Surgery, University of Dicle, Diyarbakir / Turkey.

Correspondence and reprints : Cumhuriyet Kesemenli, Dicle University Department of Orthopedic Surgery Diyarbakir / Turkey. E-mail : cumhurcevdet@hotmail.com.



**Fig. 1.** — The right tibia of a 14-year-old male patient. There was a 5.5-cm bone defect.  
**a :** Preoperative anteroposterior radiograph.  
**b :** Anteroposterior radiograph during distraction with circular external fixator.  
**c :** Anteroposterior radiograph 40 months after operation.

free bone pieces without any soft tissue connection were removed and the fractured fragments were stabilized. For initial stabilization, 17 cases received a unilateral external fixator and two were fitted into a plaster cast. Antibiotic prophylaxis using 1<sup>st</sup> generation cephalosporin for 5 days and tetanus prophylaxis were started on admission. Culture and antibiogram were performed on cases that were suspect of being infected; antibiotics were administered according to the antibiogram. Defects developed as a result of the excision of contaminated and devascularized bone fragments. The mean length of the bone defect was 6.8 cm (4-16 cm). Following soft tissue healing and wound revisions, the patients were re-operated for internal bone transport. The mean delay between trauma and beginning of distraction was 3.6 weeks (range: 2 to 7 weeks). Five of 19 patients required a myocutaneous flap and 12 of the 19 patients required skin grafting for soft tissue closure. For bone transport, a circular external fixator was used in 10 of the 12 tibial fractures (fig. 1) and a unilateral external fixator in the other two tibial fractures. A unilateral external fixator was placed on five of the femoral fractures (fig. 2) and circular external fixators were used for two femoral fractures. Subperiosteal osteotomy in the

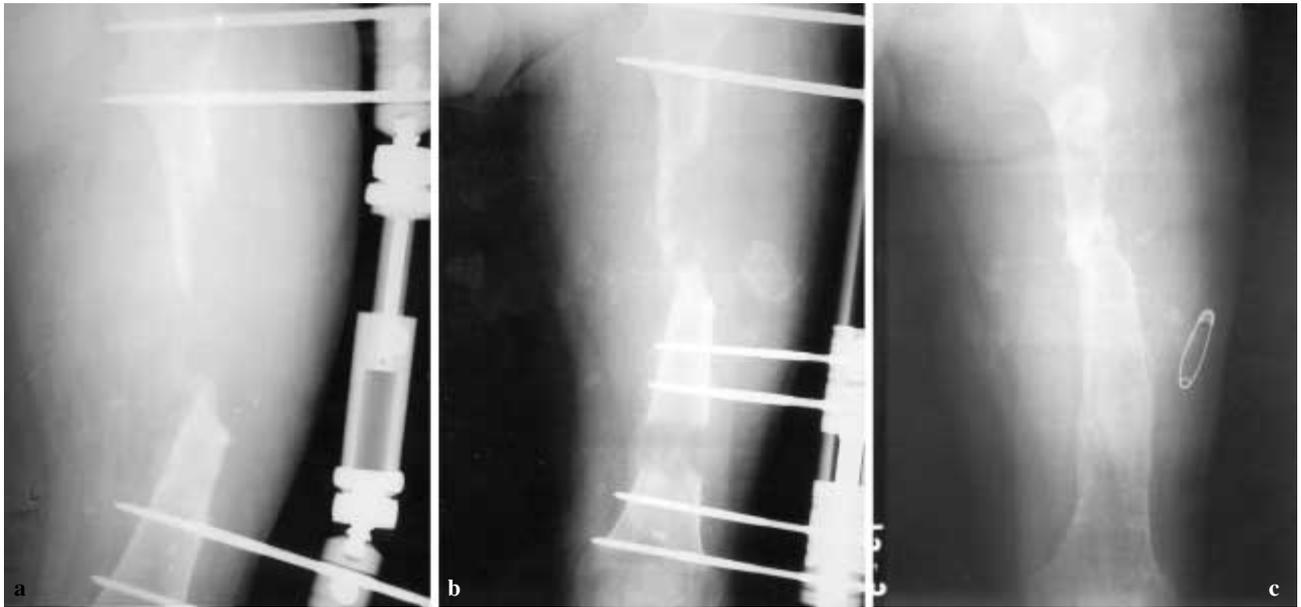
metaphyseal region was performed trifocally in a patient with a 16-cm defect, and bifocally in others (fig. 3). The osteotomy lines were checked by intraoperative xrays.

Antibiotic prophylaxis using a first generation cephalosporin was administered, beginning one hour before operation and lasting for 3 days.

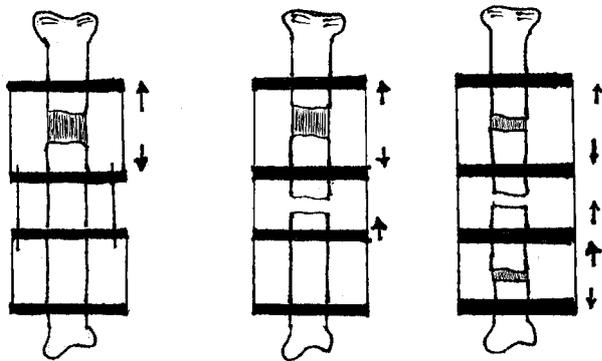
Those who underwent Ilizarov external fixation were mobilized with partial weight bearing as of the second postoperative day and with full weight bearing after the second week. The cases who underwent unilateral external fixation were mobilized with partial weight bearing. They were taught knee, hip and ankle joint exercises by a physiotherapist.

The callus distraction was initiated on the seventh day following operation at a rate of  $2 \times 0.5$  mm/day. The neurovascular status of the lower extremity was checked daily.

The patients were then discharged and were instructed to come back for follow-up every 10 days. They were expected to have sufficient consolidation in the regenerated bone after the targeted bone transport was achieved. Fixators were removed when adequate consolidation was seen on xrays. The distraction index and external fixation index of the patients were calculated.



**Fig. 2.** — Left femur of a 20-year-old male patient. There was a 13-cm bone defect.  
**a :** Anteroposterior radiograph with unilateral external fixator after debridement.  
**b :** Anteroposterior radiographs during distraction with unilateral external fixator.  
**c :** Anteroposterior radiograph after removal of unilateral external fixator.



**Fig. 3.** — The methods of distraction

## RESULTS

The mean follow-up was 23.6 (12-409) months. The mean length of the bone defect was 6.8 cm (4-16 cm), the distraction index was 13.3 days/cm (7.5-18 days/cm) and the external fixation index was 36.6 days/cm (32.5-46 days/cm) (table I). The mean treatment period was 8.4 months (5.5-18.9 months). Each patient underwent an average of 2.9 operations.

Pin-tract infection was observed around 15 pins (9%) following circular external fixation and around four following unilateral external fixation. It was treated by local dressings and antibiotics. One K-wire was removed because of pin-tract infection that did not respond to dressings and antibiotic treatment. No deep infection was identified. Skin invagination was observed in two cases during bone transport at the tibia. In one of these cases, there was also displacement at the fragment which was transported (fig. 4). These cases were reoperated for revision. No other problem was noted at the subsequent follow-ups.

One patient (5%) refractured one week after the fixator had been removed. He was treated by internal fixation and autogenous cancellous bone graft. Two patients (11%) showed delayed union at the target site (table II), and union was achieved after autogenous cancellous bone grafting. The patient who underwent trifocal osteotomy developed nonunion the target site (fig. 5).

Stiffness of the hip, knee, and ankle joints was detected after removal of the external fixators. However, after rehabilitation, range of motion was

Table I. — Details of 19 patients who had treatment with callus distraction

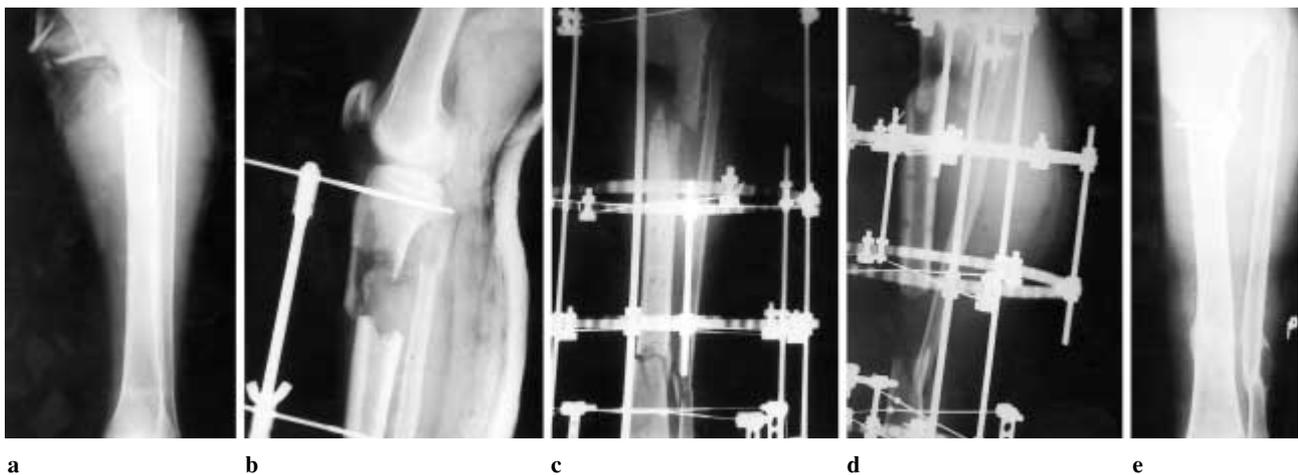
Case	Age and Sex	Etiology	Localization of defects	Size of defect (cm)	Distraction index days/cm	External fixation index days/cm
1	21/M	GSI	medial 1/3 tibia	16	7.5	40
2	20/M	GSI	distal 1/3 tibia	7	13.4	34.2
3	19/M	GSI	distal 1/3 femur	6	17	39
4	19/F	GSI	distal 1/3 tibia	7	14	34.3
5	23/M	GSI	median 1/3 tibia	9	15.7	37
6	25/M	GSI	distal 1/3 femur	8	12	35
7	23/M	TA	proximal 1/3 tibia	5	13	38
8	17/M	GSI	distal 1/3 femur	6	12.8	35
9	21/M	TA	proximal 1/3 tibia	5	14.2	37
10	13/M	GSI	median 1/3 femur	4	10.5	32.5
11	20/M	TA	medial 1/3 femur	13	16	40
12	27/M	TA	distal 1/3 tibia	5	14	36
13	9/M	TA	median 1/3 femur	5	11	33
14	41/M	GSI	median 1/3 tibia	8	18	46
15	15/M	GSI	proximal 1/3 tibia	9	15	34
16	6/F	GSI	median 1/3 femur	5	14	36
17	14/M	TA	distal 1/3 tibia	5.5	12	36
18	17/M	GSI	proximal 1/3 tibia	7	16	41
19	19/F	GSI	distal 1/3 tibia	6	12	35

GSI : Gunshot injury.

TA : Traffic accident.

M : Male.

F : Female.



**Fig. 4.** — The left tibia of a 23-year-old male patient. There was a 5-cm bone defect.

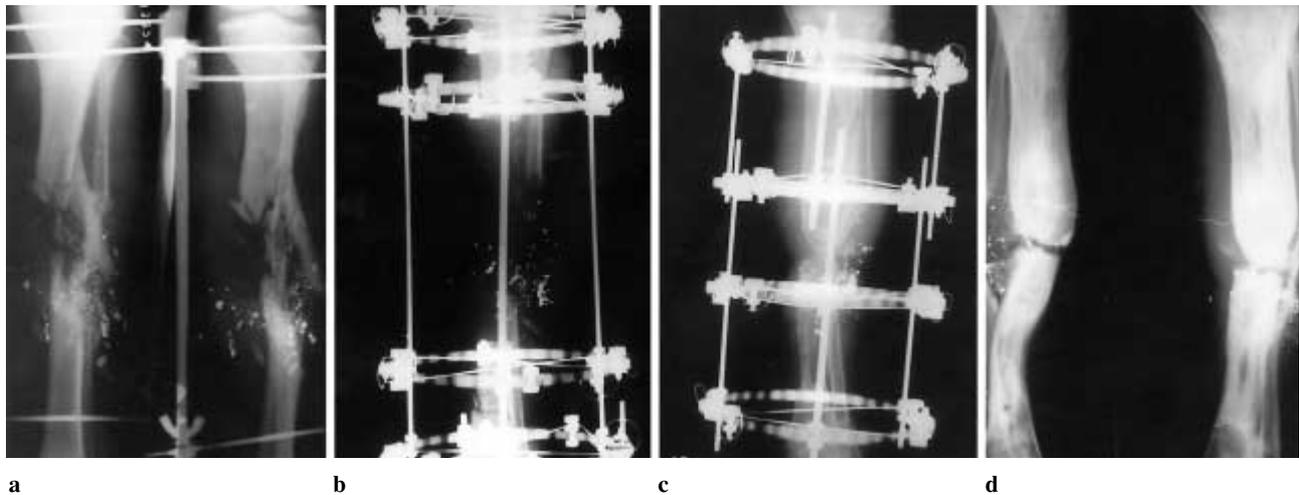
**a :** Anteroposterior radiograph after trauma.

**b :** Lateral radiograph after debridement.

**c :** Anteroposterior radiograph after osteotomy.

**d :** Anteroposterior radiograph during distraction. There was displacement.

**e :** Anteroposterior radiograph 36 months after operation.



**Fig. 5.** — Left tibia of 21-year-old male patient. There was a 16-cm bone defect.  
**a :** Radiograph after initial stabilization.  
**b :** Radiograph after trifocal osteotomy.  
**c :** Radiograph during distraction.  
**d :** Radiograph showing nonunion.

Table II. — Complications in 19 patients who had treatment with callus distraction

Complication	Number of Patients	Rate
Pin-tract infection	15 K-wires, 4 Schanz pins	9%, 10%
Deep infection	0	0
Early consolidation	0	0
Refracture	1	5%
Delayed union, nonunion	2	10%
Fragment displacement	1	5%
Pes equinus	0	0
Skin infolding	2	10%
Nonunion	1	5%

nearly normal, and did not affect the function of the patients. It was observed that the patients tolerated unilateral external fixation better and found it more comfortable than circular external fixation.

During the course of treatment, each patient underwent an average of 11.6 radiographic examinations (range : 8 to 24).

## DISCUSSION

The treatment of bone defects is a debated and difficult issue. In the past, the treatment of choice was amputation, whereas several other options are now available, such as autogenous cancellous bone grafts, vascularized bone grafts, allografts and cal-

lus distraction. The use of Bone Morphogenetic Protein is still experimental (5, 10, 13).

Autogenous bone grafts have been used successfully for the management of bone defects up to 6 to 10 cm (1, 2, 7). However, this method requires large volumes of graft with only a limited supply available. It requires a long period before corticization of the graft occurs and makes weight bearing possible. Stress fractures may develop at the graft site, as well as nonunion at the bone-graft junction (3, 10, 15).

Free vascularized bone grafts have been used since the seventies. It has been reported that the mean success rate for segmental bone defects treated by free vascularized bone graft is 69% and that

15% of the cases required secondary surgical treatment (4, 10, 14). They require microsurgery techniques, long-term immobilization and bracing. Nonunion at the junction of the bone and graft, stress fracture at the graft site and the fact that grafts require up to 3 years to achieve normal bone dimensions are further disadvantages of the method (9, 14, 15).

Masquelet *et al.* reported a series of 35 cases of bone reconstruction of large diaphyseal defects performed in two stages. In weight bearing on diaphyseal segments normal walking was possible at 8.5 months on average (8).

Callus distraction was suggested by Ilizarov for the treatment of segmental bone defects ; it is recommended for defects greater than 3 cm (12). The treatment of bone defects by callus distraction is a biological method. It offers significant advantages ; it can be applied to a defect of any dimension and length and does not require long-term immobilization and massive bone grafts (4, 6, 7). Nineteen patients with defects greater than 3 cm were treated by bone transport in our clinic taking into account the above-mentioned advantages. In the literature, it has been reported that the mean treatment period for the management of 6.8-cm segmental bone defects by callus distraction was 7-9 months with a fixation index of 33.4 days/cm (4, 10). The mean bone defect in our cases was 6.8 cm long, and our fixation index was 36.6 days/cm. The mean recovery period was 8.4 months. Pailey *et al.* (9) recommended trifocal distraction in cases with a defect greater than 8 cm. We performed trifocal osteotomy in one case with a defect of 16 cm.

Complications such as pin-tract infection, delayed union, deep infection, refracture, fragment displacement, and skin infolding have been noted in patients undergoing callus distraction (10). Pin-tract infection developed with 15 of the K-wires (9%) and four (10%) of the Schanz pins in our series. They were treated with oral antibiotics and local dressings. No deep infection occurred. One patient (9%) who presented refracture underwent secondary cancellous autografting. The infolding of soft tissue and its intrusion into the gap region may prevent the transport of bone (10). We have

observed soft tissue infolding in two cases. These patients were treated by soft tissue revision.

In cases who underwent callus distraction, delayed union may occur at both the docking site and distraction region. If there is delayed union, autogenous cancellous grafting may be performed (4, 10). We applied cancellous grafts obtained from the iliac crest to the target site in two cases with delayed union, and we achieved union in these cases.

Displacement of the transported fragment may be observed during bone transport (4, 10). Combined intramedullary nailing can be employed in order to prevent it (11). In one case with a Gustilo Type 3B open fracture who underwent unilateral external fixation and bone transport, we identified ventral displacement of the fragment and skin infolding. The patient underwent skin and fixator revision.

Radiographic checks must be performed every two weeks during distraction and once a month during maturation (12). As a result xrays were taken 11.6 (8-24) times on average during follow-up and treatment. Increased exposure of the patients to radiation and increased treatment cost may be viewed as disadvantages of this treatment.

In conclusion, with the callus distraction method, treatment of segmental bone defects can obtain biological bone consolidation and does not require immobilization. Although both unilateral and circular-type external fixators can be used during the treatment, unilateral fixators may be better tolerated by the patients, especially at the femur. However, the increased exposure to radiation over that of conventional methods can be viewed as one disadvantage of this method.

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### SAMENVATTING

*C. KESEMENLI, M. SUBASI, T. KIRKGOZ, A. KAPUKAYA, H. ARSLAN. Behandeling van traumatische botdefecten door callusdistractie.*

In deze studie worden de resultaten geëvalueerd van callus distractie als behandeling van traumatische botdefecten bij 19 patiënten (16 mannelijke en 3 vrouwelijke patiënten met een gemiddelde leeftijd van 19,4 jaar,

variërend van 6 tot 41 jaar). Bij 13 was het defect een gevolg van schotwonden, bij 6 ging het om gevolgen van verkeersongevallen. Het defect lag ter hoogte van de tibia in 12, en ter hoogte van het femur in 7 gevallen. De gemiddelde opvolgingsduur betrof 23,6 maanden (12-40). Het botdefect was gemiddeld 6,8 cm lang (4-16 cm). De gemiddelde distractiesnelheid bedroeg 13,3 dagen per cm (7,5 tot 18 dagen per cm). De duur van uitwendige fixatie bedroeg gemiddeld 36,6 dagen per cm, variërend van 32,5 tot 46 dagen per cm. In 15 gevallen (9%) werd pintrack infectie vastgesteld bij gebruik van een ring fixator, tegen 4 (10%) bij gebruik van een unilaterale externe fixator. Geen enkel geval ontwikkelde diepe infectie. In een geval ontstond een re-fractuur (5%). Trage heling ter hoogte van de distale pool werd genoteerd in 2 gevallen (11 %). Eén geval leidde naar pseudarthrosis.

Distractie osteogenese is volgens de auteurs een degelijke optie bij de behandeling van grote botdefecten.

### RÉSUMÉ

*C. KESEMENLI, M. SUBASI, T. KIRKGOZ, A. KAPUKAYA, H. ARSLAN. Traitement de pertes de substance osseuse traumatiques par transport osseux.*

Les auteurs ont étudié rétrospectivement les résultats obtenus par la méthode d'ostéogénèse en distraction dans 19 cas de pertes de substance osseuse d'origine traumatique.

L'âge moyen des patients était de 19,4 ans (6 à 41) ; 16 patients étaient de sexe masculin. La perte de substance osseuse était due à un traumatisme à haute énergie par arme à feu dans 13 cas, à un accident de la voie publique dans les 6 autres. Seize lésions siégeaient au tibia et 7 au fémur. Le suivi moyen était de 23,6 mois (12 à 40). La perte de substance osseuse mesurait en moyenne 6,8 cms (extrêmes: 4 et 16 cms), l'indice de distraction était de 13,3 jours/cm (7,5 à 18) et l'indice de fixation externe de 36,6 jours/cm (32,5 à 46). Il y a eu 15 infections sur broches avec les fixateurs externes annulaires (9%) et quatre après fixation externe unilatérale (10%). Il n'y a eu aucune infection profonde. Un patient a présenté une refracture (5%) et deux (11%) ont présenté un retard de consolidation au site terminal. Un patient a présenté une pseudarthrose à ce niveau.

La méthode d'ostéogénèse en distraction apparaît comme une option intéressante pour traiter des pertes de substance osseuse étendue d'origine traumatique.