Original Article

Our Clinical and Radiological Results in the Treatment of Bone Transport with Ilizarov External Fixator in Patients with Segmental Tibial Defects. Is Depression Associated with Poor Outcomes?

Abstract

Objective: The aim of this study was to evaluate the clinical and radiological results of patients who underwent bone transport with Ilizarov external fixator in the treatment of tibial defects due to traumatic causes, and to investigate the factors that have a positive or negative effect on the results. **Patients and Methods:** From a total of 30 patients with tibial segment loss due to traumatic causes treated with bone transport with an Ilizarov external fixator between 2013 and 2020 in the Department of Orthopedics and Traumatology of the Faculty, 25 with adequate examinations and follow up were included in this study and were evaluated retrospectively. The patients were grouped according to the etiology of bone loss, demographic characteristics, Paley's pseudoarthrosis classification and Solomin's long bone defect classification. The results were evaluated according to the Association for the Study and Application of the Method of Ilizarov (ASAMI) outcome criteria. **Results:** The 25 patients in the study comprised 20 males and 5 females with an average age of 44.80 ± 18.51 years. According to the Paley pseudoarthrosis classification, 16 (64%) patients were Type B1, 5 (20%) were Type B2, and 4 (16%) were Type B3. According to the Solomin long bone defect classification, 4 (16%) patients were Type B2, 14 (56%) were Type C1, and 7 (28%) were Type C2. In some patients, due to the fixation problem, early fixation was achieved with minimally invasive plate osteosynthesis or intramedullar nailing by removing the Ilizarov fixator after the necessary length and alignment was achieved for the purpose of early rehabilitation. Early fixation was achieved before consolidation was completed in 16 of 25 patients. Fixator duration was 360 ± 130.77 days in the group without additional fixation and external fixation index (EFI) was 61.63 ± 29.81 days/cm, while the fixator duration was 273.33 ± 116.82 days in the early fixation group, and EFI was 57.22 ± 29.05 day/cm. Complications were evaluated according to Paley's criteria. A total of 39 complications were recorded, the most common being pin tract infection. The ASAMI bone results were found to be excellent in 7 patients, good in 9, moderate in 4, and poor in 5. The functional results were excellent in 5 patients, good in 11, moderate in 4, and poor in 5. In addition, 5 (20%) of 25 patients whose results were evaluated had depressive illness. Moreover, the results of these patients were found to be poor according to the ASAMI criteria. **Conclusion:** The Ilizarov method is a very safe and successful option in the treatment of open fractures with tibial segment loss resulting from high-energy traumas. Nevertheless, when making the decision for treatment with this method, the patient's current depressive disorder should be taken into consideration in addition to the clinical problems of the patients.

Keywords: *Bone transport, distraction osteogenesis, Ilizarov external fixator, tibial bone defect*

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Introduction

Tibial bone defects can be due to open fractures resulting more from high-energy acute trauma or debridements performed, sequelae following trauma, resection due to tumour or bone infection, nonunion, or congenital defects.[1-5] Infected or noninfected tibial bone defects may be seen frequently in clinical practice and the presence of related soft tissue defects creates significant difficulty in treatment for orthopedic surgeons.[1,6,7]

The available evidence reports that the bone and functional results of the Ilizarov distraction method in the treatment of tibial bone defects are satisfactory.[8-16]

Distraction osteogenesis is based on the principles of the Ilizarov method. Bone transport is used to reconstruct the residual segmental defect.[11,17] This has the advantages of allowing weight-bearing

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on the extremity and providing a mechanical environment during the fracture healing process because of good stability, preventing long-term immobility of the joint, increasing blood circulation in the extremity, regaining extremity functions, and eliminating shortness with segment shift in cases with infection or bone loss. This has also become the preferred method in many centres for large segmental defects for which bone graft and large amounts of soft tissue are not required.[5,9,18,19]

In previous studies related to Ilizarov distraction osteogenesis or a combined technique for tibia segmental defects, the methods, evaluation criteria, and results are extremely heterogenous.[9] Moreover, from an investigation of literature, there can be seen to be relatively few current, original studies related to the treatment outcomes of distraction osteogenesis with an Ilizarov external fixator and the bone transport method used in traumatic tibial bone defects.[4,6,13,20] On the other hand, some previous studies have reported that treatment with the Ilizarov external fixator causes psychiatric symptoms such as depression and anxiety.[21,22] However, as far as we could investigate, we could not find any information about whether the current depressive illness affects the results of bone transport treatment with Ilizarov external fixator in patients with segmental tibial defect.

The questions to which answers were sought in this research were, (1) Is Ilizarov external fixator with bone transport a successful and reliable method in tibial bone defects of traumatic origin? and (2) Does the depressive disorder of the patients affect the outcomes?

Therefore, the aim of this study was to evaluate the clinical and radiological results of patients treated with Ilizarov external fixator and bone transport for traumatic tibial defects, and to investigate how the depressive disorder affects outcomes.

Patients and Methods

A retrospective review was made of 30 patients treated with Ilizarov external fixator with the bone transport method for segmental bone loss in the tibia associated with traumatic causes in the orthopedics and traumatology clinic between January 2013 and January 2020. The study included patients aged ≥18 years, with a tibia bone defect of traumatic causes, who had full medical records, had attended follow-up examinations regularly, and with at least 2 years of follow up. Patients were excluded from the study if they were aged <18 years, had defects associated with causes other than trauma and infection, had incomplete medical records, had comorbidities which would delay wound healing (e.g., cancer, diabetes mellitus), or were lost to follow up. In addition, the medical records of all patients were reviewed in terms of diagnosed psychiatric illness or not. Out of a total of 30 patients, 5 were excluded from the study according to the exclusion criteria, and the results of 25 patients who met the inclusion criteria were investigated.

In the last records of the patients, 3 had a diagnosis of depression and 2 had an anxiety disorder. However, when all previous records were reviewed, the common depressive disorder diagnoses were taken into account. Although anxiety and depression are considered as two separate entities according to the diagnostic criteria, depression and anxiety symptoms may appear together in patients with a high frequency.[23,24]

A total of 25 patients who met the criteria were included in the study. A record was made for each patient of demographic data such as age, gender, affected side, and comorbidities, the mechanism of trauma causing the bone loss, history of infection, operation before the last treatment, and the time waited until transport (in months). Local ethics committee approval (Süleyman Demirel University, Date: September 18, 2020 Number: 72867572-050.01.04-138026) and patient consent were obtained for the study.

All 25 patients had bone loss. Sixteen patients had bone loss without loss of length. Length loss in 5 patients had both bone loss and length loss in 4 patients [Table 1]. Single-level osteotomy and the standard Ilizarov method were applied as the surgical technique to all the patients. Distraction was started on the postoperative 7th day. The daily distraction amount was applied as 4 mm × 0.25 mm. In the postoperative period of all patients, early joint movement according to patient tolerance and weight-bearing mobilization was achieved. In this period, the patient was taught about distraction. The patients were evaluated radiologically and clinically at periodic controls. The Ilizarov fixator was removed in patients with the required length, alignment, and union. However, in some patients who requested early removal of the Ilizarov fixator, and in patients who were excessively affected psychosocially by the device and/or to shorten the external fixator time, it was removed and fixation was provided with minimally invasive plate osteosynthesis (MIPO) or intramedullar nailing (IMN), to be able to obtain weight-bearing and early joint movement before the development of sufficient consolidation. In these patients, when the required length and desired alignment were achieved, early fixation with MIPO or IMN was provided following the completion of the distraction phase. Early fixation was achieved with MIPO in patients who underwent metaphyseal osteotomy due to their deformity or had a narrow intramedullary canal. On the other hand, IMN was applied in patients with poor skin circulation and/or risk of infection.[25,26]

Hospital depression scale was performed by requesting psychiatry consultation in patients with depression diagnosis and depressive symptoms. Those with high depressive scores were evaluated according to Diagnostic and Statistical Manual of Mental Disorders, Fifth

Table 1: Statistical analysis of association for the study and application of the method of Ilizarov bone results

	ASAMI bone results		
	Poor-moderate (*n*=9), *n* (%)	**Good-excellent (*n*=16), *n* (%)**	***P***
Age (years)	44.11±15.68	45.19±20.41	0.892*
Gender			
Male	7 (77.78)	13 (81.25)	0.835+
Female	2 (22.22)	3 (18.75)	
Side			
Right	6 (66.67)	11 (68.75)	0.915+
Left	3 (33.33)	5 (31.25)	
Etiology			
Traffic accident outside vehicle	1 (11.11)	1 (6.25)	0.451+
Traffic accident inside vehicle	4 (44.44)	5 (31.25)	
Firearms	1 (11.11)	3 (18.75)	
Farming	0	2 (12.50)	
Motorcycle	0	3 (18.75)	
Fall from height	3 (33.33)	2 (12.50)	
Gustilo Anderson classification			
3 A	3 (33.33)	9 (56.25)	0.389+
3 B	3 (33.33)	5 (31.25)	
3 C	3 (33.33)	2 (12.50)	
Number of operations before transport			
1	4 (44.44)	5 (31.25)	0.294+
2	3 (33.33)	10 (62.50)	
3	2 (22.22)	1 (6.25)	
Waiting time before transport (months)	8.67±4.9	17.75±18.45	0.909*
Paley pseudarthrosis clasification			
B1	5 (55.56)	11 (68.75)	0.767+
B2	2 (22.22)	3 (18.75)	
B3	2 (22.22)	2 (12.50)	
Solomin classification			
B2	0	4 (25.00)	0.262+
C1	6 (66.67)	8 (50.00)	
C2	3 (33.33)	4 (25.00)	
Bone loss (cm)	5.32±2.49	6.13±3	0.513*
Smoking			
No	5 (55.56)	5 (31.25)	0.234+
Yes	4 (44.44)	11 (68.75)	
Psychiatric diseases			
Absent	4 (44.44)	16 (100.00)	0.001+
Present	5 (55.56)	0	
Operation performed			
Bifocal ant	6 (66.67)	13 (81.25)	0.412+
Bifocal ret	3 (33.33)	3 (18.75)	
Fixator duration (days)	323.33±136.47	283.13±119.48	0.305*
EFI day/cm	69.5±34.35	52.24±23.97	0.223*
Dahl *et al*. - pin tract ınfection classification			
Grade 2	1 (11.11)	4 (25.00)	0.411+
Grade 3	6 (66.67)	11 (68.75)	
Grade 4	2 (22.22)	1 (6.25)	

*Mann–Whitney *U*-test, +Chi-square test. ASAMI: Association for the study and application of the method of Ilizarov, EFI: External fixation index

Edition criteria by psychiatric examination. Psychiatric interviews were made with the diagnosed patients. Psychotherapy was done. Afterward, antidepressant treatment was started.

At the final follow-up examination, the patients were evaluated in respect of functional results, and according to pain, physical activity, limping, soft tissue dystrophy, and ankle contracture in the physical examination. Infection,

limb length discrepancy, and other complications were recorded.

The patients were classified according to the Gustilo-Anderson[27] open fracture classification, the soft tissue status in closed fractures, and the Tscherne classification.[28] Bone loss in the patients was classified according to the Paley pseudarthrosis and Solomin long bone defect classifications.[29,30] A record was made of the amount of bone loss (cm) and transport distance, complications related to previous operations, pseudarthrosis type, and transport direction.

For the clinical evaluation, the postoperative results of the bone and functional criteria of Paley modified by the Association for the Study and Application of the Method of Ilizarov (ASAMI) were used.[29] In the radiological evaluation, the consolidation time was determined and the time to union (months) was defined as the observation of continuation in at least 3 cortices.[4] Complications were evaluated according to the Paley complication criteria[31] and the complication classification of Dahl *et al*.[32] Finally, evaluation was made of the effects of early mobilisation following fixation with MIPO or IMN after removal of the fixator in the early period of consolidation.

Statistical analysis

The statistical analyses of this study were performed using NCSS (Number Cruncher Statistical System) 2007 Statistical Software (Utah, USA). Descriptive statistics were reported as mean ± standard deviation values. Conformity of the data to normal distribution was assessed with the Shapiro–Wilk test, and in the comparisons of paired groups of variables not showing normal distribution, the Mann–Whitney *U*-test was applied. The Chi-square test was used in the comparisons of categorical data.

Results

Evaluation was made of 25 patients, comprising 20 (80%) males and 5 (20%) females. Tibial defective nonunion was present in the right tibia of 17 (68%) cases and in the left tibia of 8 (32%) cases. The traumatic etiology causing the tibial bone defect was determined as traffic accident within the vehicle in 9 (36%) patients, a fall from height in 5 (20%), firearms injury in 4 (16%), motorcycle accident in 3 (12%), traffic accident outside the vehicle in 2 (8%), and farming injury in 2 (8%).

The fracture type was Type 3 according to the Gustilo-Anderson open fracture classification in all the patients; Type 3A in 12 (48%), Type 3B in 8 (32%), and Type 3C in 5 (20%). According to the Paley pseudarthrosis classification, 16 (64%) patients were Type B1, 5 (20%) were Type B2, and 4 (16%) were Type B3. The evaluation of the bone losses of the patients according to the Solomin long bone defect classification showed that 4 (16%) patients were Type B2, 14 (56%) were Type C1, and 7 (28%) were Type C2.

When the number of operations before transport were examined, 9 (36%) patients had undergone 1 operation, 13 (52%) had undergone 2 operations, and 3 (12%) had undergone 3 operations. The operation most performed was plate-screw surgery. The presence of comorbidities and/or risk factors was examined; 15 (60%) patients were smokers and 10 (40%) were nonsmokers, 20 (80%) had no history of psychiatric disease and 5 had a history of psychiatric disease (major depressive disorder in 3, and anxiety disorder in 2). In summary, 5 (20%) of 25 patients evaluated had depressive illness.

All patients underwent a single osteotomy; 19 (76%) with antegrade, and 6 (24%) with the retrograde treatment method. According to the ASAMI bone outcome criteria, the results were excellent in 7 (28%) patients, good in 9 (36%), moderate in 4 (16%), and poor in 5 (20%). No statistically significant difference was determined between the ASAMI bone poor-moderate group and the good-excellent group in respect of mean age, gender, affected side, etiology, number of operations before transport, waiting time to transport, Paley pseudarthrosis classification, Solomin long bone defect classification, smoking status, and type of operation [Table 1]. The Gustilo-Anderson typing of open fractures did not make any proportional statistically significant difference between the ASAMI bone good-excellent and poor-moderate groups (P = 0.389) [Table 1]. A history of psychiatric disease was determined at a statistically significantly higher rate in the ASAMI bone poor-moderate group compared to the ASAMI good-excellent group (P = 0.001) (Chi-square test).

The mean fixator duration was determined to be 323.33 days in the ASAMI bone poor-moderate group and shorter at 283.13 days in the ASAMI bone good-excellent group. The external fixation index (EFI) was 69.5 day/cm in the ASAMI bone poor-moderate group and lower at 52.4 day/cm in the ASAMI bone good-excellent group. No statistically significant difference was determined between the groups in either of these two parameters [Table 1].

According to the ASAMI functional outcome criteria, the results were excellent in 5 (20%) patients, good in 11 (44%), moderate in 4 (16%), and poor in 5 (20%). No statistically significant difference was determined between the ASAMI functional outcome poor-moderate group and the good-excellent group in respect of mean age, gender, affected side, etiology, number of operations before transport, waiting time to transport, Paley pseudarthrosis classification, Solomin long bone defect classification, smoking status, and type of operation [Table 2]. The Gustilo-Anderson typing of open fractures did not make any statistically significant difference between the ASAMI functional good-excellent and poor-moderate groups (P = 0.072). A history of psychiatric disease was determined at a statistically significantly higher rate in the ASAMI functional poor-moderate group compared

Table 2: Statistical analysis of association for the study and application of the method of Ilizarov functional results

	ASAMI functional results		
	Poor-moderate (*n*=9), *n* (%)	**Good-excellent (*n*=16), *n* (%)**	***P***
Age (years)	39.44±16.58	47.81±19.35	0.282*
Gender			
Male	7 (77.78)	13 (81.25)	0.835+
Female	2 (22.22)	3 (18.75)	
Side			
Right	5 (55.56)	12 (75.00)	0.317+
Left	4 (44.44)	4 (25.00)	
Etiology			
Traffic accident outside vehicle	1 (11.11)	1 (6.25)	0.872+
Traffic accident inside vehicle	4 (44.44)	5 (31.25)	
Firearms	1 (11.11)	3 (18.75)	
Farming	0	2 (12.50)	
Motorcycle	1 (11.11)	2 (12.50)	
Fall from height	2 (22.22)	3 (18.75)	
Gustilo Anderson classification			
3 A	3 (33.33)	9 (56.25)	0.072+
3 B	2 (22.22)	6 (37.50)	
3 C	4 (44.44)	1 (6.25)	
Number of operations before transport			
1	4 (44.44)	5 (31.25)	0.802+
2	4 (44.44)	9 (56.25)	
3	1 (11.11)	2 (12.50)	
Waiting time before transport (months)	7±2.55	18.69±18.14	0.332*
Paley pseudarthrosis clasification			
B1	5 (55.56)	11 (68.75)	0.767+
B2	2 (22.22)	3 (18.75)	
B3	2 (22.22)	2 (12.50)	
Solomin classification			
B2	1 (11.11)	3 (18.75)	0.838+
C1	5 (55.56)	9 (56.25)	
C2	3 (33.33)	4 (25.00)	
Bone loss (cm)	5.34±2.49	6.12±3.00	0.589*
Smoking			
No	5 (55.56)	5 (31.25)	0.234+
Yes	4 (44.44)	11 (68.75)	
Psychiatric diseases			
Absent	4 (44.44)	16 (100.00)	0.001+
Present	5 (55.56)	0	
Operation performed			
Bifocal ant	6 (66.67)	13 (81.25)	0.412+
Bifocal ret	3 (33.33)	3 (18.75)	
Fixator duration (days)	310±117.15	290.63±131.78	0.408*
EFI day/cm	66.33±31.04	54.02±27.32	0.295*
Dahl *et al*. - pin tract ınfection classification			
Grade 2	1 (11.11)	4 (25.00)	0.411+
Grade 3	6 (66.67)	11 (68.75)	
Grade 4	2 (22.22)	1 (6.25)	

*Mann–Whitney *U*-test, +Chi-square test. EFI: External fixation index

to the ASAMI functional good-excellent group (P = 0.001). The five patients with a history of psychiatric disease were all in the group with poor functional results according to the ASAMI criteria.

The mean fixator duration was determined to be 310 days in the ASAMI functional poor-moderate group and shorter at 290 days in the ASAMI functional good-excellent group. The EFI was 66.3 day/cm in the ASAMI functional

poor-moderate group, and lower at 54.02 day/cm in the ASAMI functional good-excellent group. No statistically significant difference was determined between the groups in either of these two parameters [Table 2].

EFI was shorter in the early detection group [Table 3]. The EFI value was 57.22 day/cm in the patient group applied with fixation and 61.63 day/cm in the patients not applied with early fixation. The fixator duration was shorter and the EFI values were lower in the patients applied with fixation in the early period of consolidation [Table 3].

A total of 39 complications were recorded in these 25 patients, as a problem in 25, a hindrance in 9, and a real complication in 5. No neurovascular damage occurred while advancing the K-wire in any patient. In the nine patients with a hindrance, a delay in maturation was determined in the target region. Of the five patients with actual complication, peroneal nerve damage was present in one preoperatively, which was treated by transfer of the posterior tibial tendon in the period after transport. In one patient, a defect was present within the tibia distal joint surface before transport, and this was treated with tibiotalar arthrodesis. Patients who developed ankle contracture improved with physical therapy. No patient developed knee contracture. The complications are summarised in Table 4. In addition, patients with a history of psychiatric illness and poor functional outcomes according to the ASAMI criteria did not have the above-mentioned complications.

Table 3: Statistical analysis of early fxation after Ilizarov

	Early fixation after Ilizarov		*P*
	No	Yes	
Fixator duration (days)	360±130.77	273.33±116.82	0.106*
EFI day/cm	61.63±29.81	57.22±29.05	0.716*

*Mann–Whitney *U*-test, EFI: External fixation index

Table 4: Complications and treatments

Complications, *n* (%)	Number of patients	Treatments
Problem: 25 (64)		
Grade 2–3 pin tract infection	22	Dressing and antibiotherapy
Grade 4 pin tract infection	3	Debridement
Hindrance: 9 (23)		
Delayed maturation in the target region	5	Akerdeon technique
	4	Autologous grafting and vitalisation with drilling
Real complication: 5 (13)		
Early consolidation	1	Repeated osteotomy
Axial deviation	2	Frame modification
Peroneal nerve damage	1	Tibialis posterior tendon transfer
Ankle arthrosis	1	Ankle arthrodesis

The preoperative, postoperative, and follow-up radiographs are shown in Figures 1a-h and 2a-h of 1 patient applied with bone transport with Ilizarov external fixator because of tibia bone defect [Case 1; Figure 1] and of 1 patient treated with the same method, but then applied with MIPO following consolidation and removal of the fixator [Case 2; Figure 2].

Discussion

The main results of this study showed that in the bone and functional outcomes of 25 patients with a tibial defect of mean 5.84 cm treated with the Ilizarov distraction technique, good or excellent clinical results were obtained in 64%. Another result of this study is that it was investigated whether the current depressive disorder of the patients could be related to clinical outcomes. Investigation of psychiatric disease history like as depressive disorder in patients to be treated with this technique will contribute to increasing the success and follow-up of treatment.

Various methods have been reported in the treatment of bone defects, including the use of spongious and cortical bone grafts, allografts, pedicled fibula, iliac wing grafts, and human bone morphogenetic protein. Each of the methods has advantages and disadvantages. In a study that compared the results of autograft and distraction osteogenesis, Cierny and Zorn.[33] treated 21 patients with the Ilizarov distraction osteogenesis technique and 23 patients with traditional grafting techniques. Successful treatment was achieved in 71% of the patients applied with the Ilizarov method and in 74% of the other group. Complications were determined as 33% and 60%, respectively. It was concluded that treatment with the Ilizarov method was cheaper, simpler, quicker, and could be controlled. The Papineau technique is another grafting option used in the treatment of bone losses. In a study by Green,[3] 17 of 32 patients were followed up with fixator by grafting with the Papineau technique, and 15 were treated with the Ilizarov segment transport method. Although the EFI values were found to be similar in both groups, disadvantages of the Papineau technique were reported to be that it had 3 stages, the length of stay in hospital was longer, and the skin covering the graft region was very thin and fragile.

Successful results have been reported in cases treated with the distraction osteogenesis technique. In a study of 25 tibia fracture patients including 22 atrophic and 3 hypertrophic nonunion, mean bone loss was reported to be 6.2 cm and the distraction osteogenesis technique was used in treatment. Limb length discrepancy was reported in 19 patients, chronic osteomyelitis in 13, bone defect in 12, and deformity in 13. The results were evaluated with bone and functional result criteria, and the bone results were 18 excellent, 5 good, and 2 poor, while the functional results were 16 excellent, 7 good, 1 moderate, and 1 poor. Cattaneo *et al*.[34] sucessfully treated 28 patients with tibia segmental bone defect and infected nonunion with the distraction

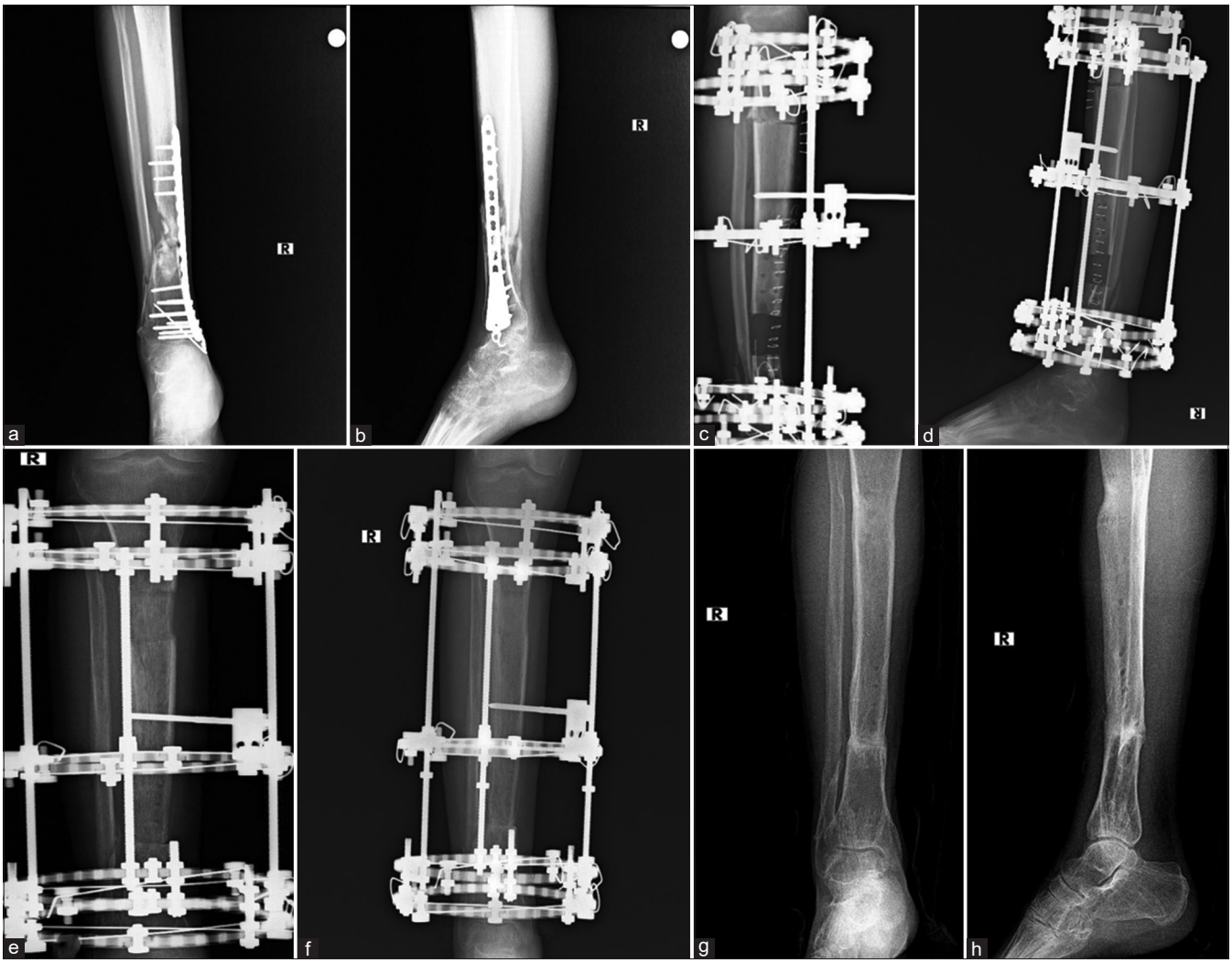

Figure 1: A 27-year-old male patient diagnosed with right tibia fracture following a traffic accident inside the vehicle, with plate-screw fixation applied at another centre. The patient presented with a diagnosis of infected pseudarthrosis. The plate and screws were removed and 3.5 cm bone debridement was performed. In the same session, the bifocal antegrade bone transport procedure was applied with Ilizarov. The fixator duration was 180 days and the external fixation index was determined as 51.4 day/cm. The Association for the Study and Application of the Method of Ilizarov bone and functional results were evaluated as excellent. (a and b) preoperative anterior posterior (AP), lateral radiographs, (c and d) postoperative day 1 AP, lateral radiographs, (e) postoperative 3-month AP radiograph, (f) postoperative 6-month AP radiograph, (g and h) postoperative 1-year AP, lateral radiographs

osteogenesis method. The functional results were evaluated as good-excellent in 21 patients, moderate in 6, and poor in 1. Dendrinos *et al*.[35] treated 28 patients with tibial defect with mean bone loss of 6 cm (range: 2–13 cm) with the distraction osteogenesis technique. The bone results obtained were 14 patients excellent, 8 good, 1 moderate, and 5 poor, while the functional results were reported as 7 excellent, 11 good, 4 moderate, and 6 poor. In another study by Paley and Maar[4] the mean tibial bone defect was 10 cm in 19 patients treated with the distraction osteogenesis method using Ilizarov external fixator. The bone results were reported as 15 patients excellent, 3 good, and 1 moderate, and the functional results were 12 excellent, 6 good, and 1 poor. Song *et al*.[36] treated 27 patients with a tibial defect with the distraction osteogenesis method using Ilizarov external fixator. The treatment results were evaluated in this patient group with mean bone defect of 8.3 cm (range: 3–20 cm). The bone results were reported as 14 patients excellent, 8 good, 2 moderate, and 5 poor and the functional results were excellent in 11 patients, good in 11, moderate in 2, and poor in 3. Maini *et al*.[37] evaluated 30 patients diagnosed with infected nonunion who were treated with the distraction osteogenesis method using Ilizarov external fixator. The bone results obtained were 21 (70%) patients excellent, 3 (10%) good, and 6 (20%) poor, while the functional results were reported as 8 (26.7%) excellent, 12 (40%) good, 3 (10%) moderate, and 7 (23.3%) poor.

In the current study, the bone and functional results were evaluated as 65% good-excellent, and 20% poor, which were consistent with literature. It was striking that all the patients with a poor result had a history of psychiatric disease. The reasons for the poor bone and functional

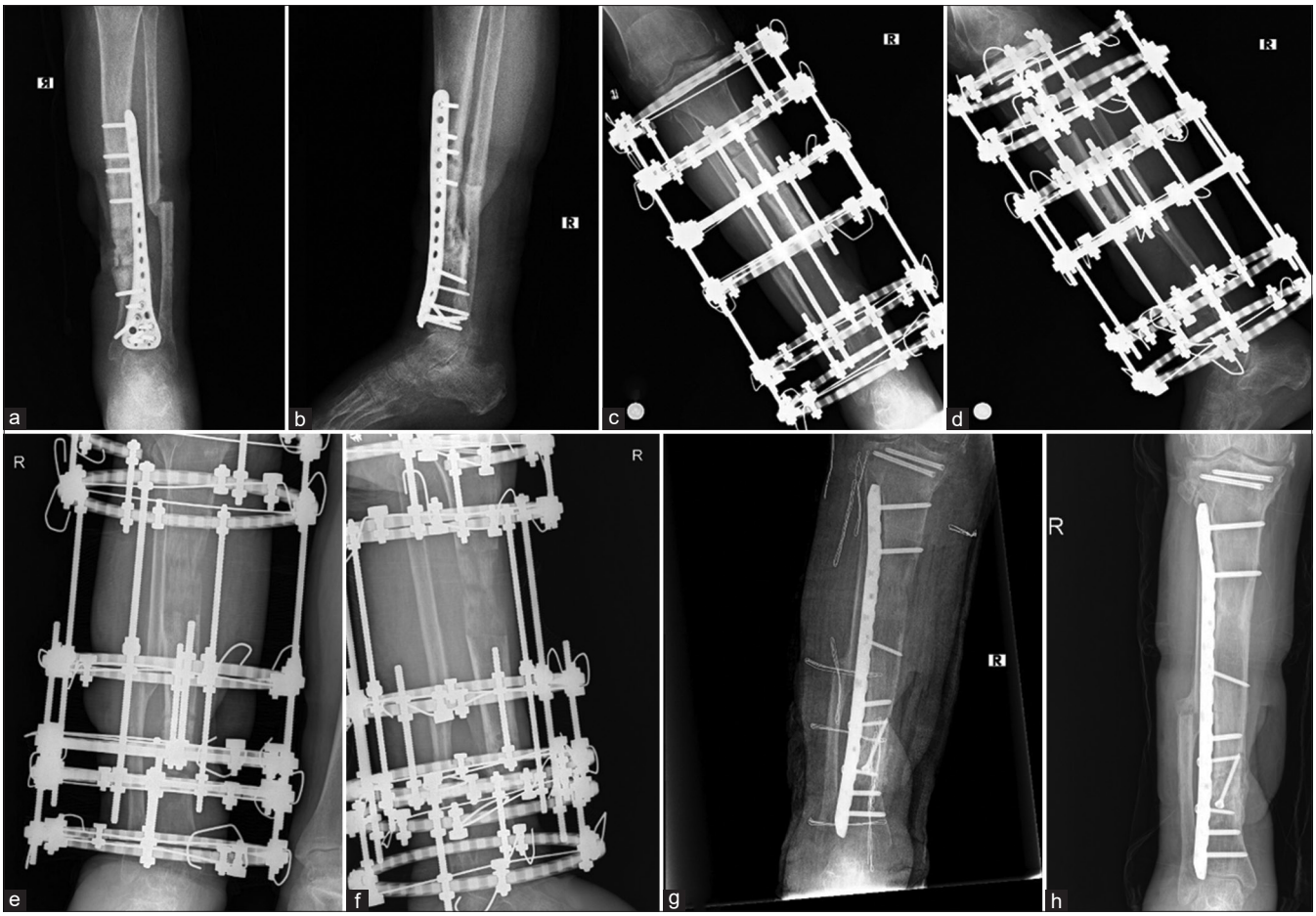

Figure 2: A 65-year-old male presented at the Emergency Department with a Gustilo-Anderson Type 3A open fracture in the right distal tibia and ipsilateral tibial plateau fracture as a result of a farming accident. The patient was followed up with a monolateral external fixator, then in the definitive treatment, fixation was made with screws in the tibial plateau region and with plate-screws in the tibial shaft region. The patient presented with a diagnosis of fistulised discharge and infected pseudarthrosis. Removal of the plate and screws, fistula excision, and 7 cm bone debridement were performed, then bifocal anteegrade bone transport with Ilizarov was applied in the same session. To shorten the fixator duration in the early period of consolidation after transport, the Ilizarov fixator was removed because of pin tract pain and difficulty in wearing the fixator, and without opening the distraction line, fibrous tissues were cleaned by opening the target region, grafting was applied, and plating with the MIPO technique. The patient was mobilised in the early period with partial weight-bearing and full joint movement. The fixator duration was 240 days and the external fixation index was determined as 34.2 day/cm. The Association for the Study and Application of the Method of Ilizarov bone results were evaluated as excellent and the functional results as good. (a and b) Before bone transport preoperative radiographs, (c and d) postoperative day 1 radiographs, (e and f) postoperative 6-month radiographs, (g) postoperative 8-month early period of consolidatio plating radiograph, (h) postoperative 19-month radiographs (11 months after plating)

results were thought to be that the patients did not make the distraction regularly, did not attend follow-up examinations regularly, and did not give sufficient importance to the treatment because of a mental health disorder.

Due to the difficulty of wearing a circular external fixator and to be able to reduce psychological problems related to concerns about the external appearance, the duration of external fixation can be reduced by removal of the external fixator and converting to the MIPO technique etc., with internal fixation when the consolidation process has been completed and/or before completion in respect of early movement.[38] Treatment can also be started with a combination of various fixation devices for these purposes.[39] In a study by Paley *et al*.,[40] the extending model of Ilizarov external fixator or a monolateral fixator combination was applied over IMN in 29 patients (3 patients bilateral). It was reported that the fixator duration was significantly shortened by obtaining weight-bearing in the early period by removing the fixator early and locking the IMN screws, and the time from reaming of the medulla to consolidation was not prolonged. In this study, for the reasons stated, early fixation with MIPO or IMN was achieved in 16 of 25 patients before consolidation was completed. These procedure was not applied immediately at the start of consolidation, but was applied according to pin tract infection and the sociocultural risk factors of the patients, which could be the reason for the difference in the current study results.

Apivatthakakul and Arpornchayanon[38] applied early plating after bone transport in the treatmet of two patients with bone defects of 7 cm and 8 cm respectively. The mean EFI value was reported as 10.4 day/cm. In a study by Oh

et al.[41] of 10 patients with a mean defect of 5.9 cm, plate fixation was applied in the early period of consolidation after external fixator, and the mean EFI value was reported as 13.4 day/cm. In the treatment of two patients with segmental tibia defect, Girard *et al*.,[42] performed distraction osteogenesis with external fixator and then fixation was achieved with a bridging plate. The mean EFI value was reported as 16 day/cm. Paley and Maar[4] treated 19 patients with tibia segment loss of mean 10.7 cm with the Ilizarov method and reported a mean EFI value of 63 day/cm in patients applied with single osteotomy. In another study by Mekhail *et al*.,[43] 19 patients with segmental bone defect were treated with bone transport with external fixator and the mean EFI was reported as 72 day/cm. Treatment with the Ilizarov method was applied to 9 patients with mean 6.3 cm tibia bone defect by Dagher and Roukoz,[44] with a reported EFI value of mean 54 day/cm. Bobroff *et al*.[20] determined a mean EFI value of 60 day/cm afte Ilizarov treatment in a group of 12 patients with mean segmental bone defect of 9.45 cm. In this current study, the EFI value outcomes was 57.22 day/cm in the patient group applied with fixation and 61.63 day/cm in the patients not applied with early fixation. The fixator duration was shorter and the EFI values were lower in the patients applied with fixation in the early period of consolidation. The EFI outcomes were found to be shorter in those who underwent early fixation, which is consistent with the literature.

A significant disadvantage of this treatment method is that patients can experience psychosocial problems because of the lengthy treatment, pain, stress, and the restrictions to daily activities.[1] In addition, some previous studies have reported that treatment with the Ilizarov external fixator causes psychiatric disease symptoms such as depression and anxiety.[21,22] However, we could not find any information regarding the treatment of depressive illness with the Ilizarov external fixator. However, in other orthopedic surgical treatments, it has been stated that psychiatric problems such as anxiety and depression may be associated with poor postoperative results.[45,46] However, no study could be found in literature related to the psychosocial problems of patients undergoing bone transport with Ilizarov distraction osteogenesis. It was significant in the results of the current study that a history of psychiatric disease was seen to have a negative effect on the clinical results of the Ilizarov bone transport treatment. This demonstrates that there will be a negative reflection on the results of patients with like depressive disorder psychiatric problems together which could be experienced because of the treatment process.

Lastly, Just as there are advantages of the use of Ilizarov external fixator in infected tissues, there are inevitable disadvantages and complications.[29] Paley classified the complications of Ilizarov application in 3 groups as problem, hindrance, and real complication.[31] According to these Paley complication criteria, a total of 39 complications developed in the current study patients, as problem in 25 patients, hindrance in 9, and real complication in 5.

Limitations of this study can be said to be that it was retrospective and the number of patients was low compared to other studies in literature. However, these cases are quite distressing and not very common. Most of the studies reported in the literature are of retrospective design. In addition, when systematic reviews and meta-analyses on the subject were reviewed, the number of patients in similar studies was reported in the range of 8–66, and the majority of them were in a retrospective design.[9,11,17] Although the number of cases in our study was small, they were within the reported ranges. There is a need for further prospective studies with larger patient series to be able to more clearly define the factors affecting the outcomes. Nevertheless, this study can be considered to have reached the primary aim, which was to investigate the EFI and outcomes and complications of bone transport for large defects and to determine psychiatric factors affecting these.

Conclusion

The Ilizarov distraction method is an extremely safe and successful option in the treatment of defective pseudarthrosis forming after fragmented open fractures caused by high-energy trauma. However, the problems experienced in the distraction process can have a negative effect on the treatment. When making the decision for treatment with this method, the patient's current depressive disorder should be taken into consideration in addition to the clinical problems of the patients.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patients have given their consent for their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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