The Egyptian Journal of Hospital Medicine (January 2025) Vol. 98, Page 247- 256

Outcome of Treatment of Segmental Tibial Defect by Ilizarov Technique

Ahmed Abdelazim Abosalem, Taher Abdelsattar Eid, Amr Saber Elsayed, Ahmed Ibrahim Zayda, Ehab Loutfy Abdelsattar Abdrabou
Department of Orthopedic Surgery, Faculty of Medicine, Menoufia University, Egypt
***Corresponding author:** Ehab Loutfy Abdelsattar, **Mobile:** (+20)1069486444, **E-mail:** dr2ehab@yahoo.com

ABSTRACT

Background: bone is one of the very few tissues in the human body that has the innate ability to mend itself after damage. Segmental tibial bone defects pose special therapy challenges that require a personalized strategy because there are numerous factors that can affect the method of treatment, such as age, host status, anatomic position, and the condition of the surrounding soft tissues.

Objective: The purpose of his study was to evaluate the Ilizarov external fixator's performance in treating segmental tibial abnormalities in adults through customized surgical methods.

Patients & methods; Twenty- four patients with segmental tibial deformities participated in this prospective study, which was carried out at Menoufia University Hospitals.

Results: Using the ASAMI rating method, 87.5% of the cases had satisfactory radiological results (34.3% good, 54.2% excellent). According to the clinical results, 83.3% of patients had adequate functional outcomes (58.3% outstanding, 25% good). Significant correlations were found between radiological and functional outcomes (p = 0.016), as well as between the duration of non-union and functional results (p = 0.046). With an overall complication rate of 62.5%, severe edema and pin tract infection were the most common problems (20.8%). 75% of patients were extremely or fairly satisfied with the overall process, which suggests that patient satisfaction was typically very high.

Conclusion: According to our research, segmental tibial anomalies of various sources could be effectively treated with the Ilizarov external fixator. With a high patient satisfaction rate and a controlled complication profile, the technique often yields good to extraordinary bone and functional results. Despite persistent challenges, particularly regarding treatment duration and complication management, the Ilizarov procedure remains a valuable tool in the orthopedic surgeon's toolbox for treating complex tibial anomalies.

Keywords: Segmental Tibial Defect, Outcome, Ilizarov Technique.

INTRODUCTION

Managing severe tibial pathologies with segmental bone abnormalities has always been extremely difficult; the challenges get worse when there is infection or associated soft tissue deficiencies. Angular anomalies, limb-length discrepancy, and soft tissue injuries can all significantly affect the patient's functional outcome and perhaps complicate the presentation. These injuries are often the result of high-energy trauma, and many patients have already experienced multiple failed surgical procedures, which further deteriorate soft tissues [(1–3)].

As a result, the affected limbs' local vascularity will be weakened, increasing the likelihood that any additional surgical procedures will fail to treat these individuals [(1-3)]. There are several approaches to treating patients with severe tibial pathology that causes anomalies in segmental bones [(4)]. Vascularized free tissue transfers [(6)], Papineau open cancellous bone grafting [(5)], and large cancellous bone grafting have been used in the past; a more recent method that seems to be beneficial for reconstructing femoral defects is the Masquelet-induced membrane technique [(7)]. The Masquelet–Ilizarov technique can treat infected nonunion tibia with extremely good results without the need for complex soft tissue procedures [(8)].

Acute treatment of segmental tibial abnormalities is sometimes limited by soft tissue restrictions, and the surgeon may not be able to entirely correct alignment or restore leg length with these specific approaches [(9)]. It makes sense to consider amputation as a last resort for patients seeking a single surgical procedure with the best-known outcome [(10)].

The utilization of Ilizarov procedures and distraction osteogenesis with external fixation [(11–13)], which have been successfully used on a regular basis for the past 25 years, has greatly expanded the options for treating this difficult problem. In contrast to other methods, Ilizarov treatments can address multiple pathological conditions simultaneously, including joint contractures, segmental bone loss, deformity, shortening, and some soft tissue issues [(14)].

The Ilizarov procedure usually involves bifocal or trifocal osteosynthesis to treat severe tibial pathologies associated with segmental bone abnormalities. This could be a different treatment option in some situations where the distal tibial defect is larger than 6 cm. It could decrease the distraction period, speed up the regeneration process, and lessen problems [(15)].

Bone is crushed at one level to create union, while distraction is applied to the same bone at one or more additional levels to promote bone mass regeneration. These limb salvage procedures include both acute shortening followed by lengthening and bone translocation [(16, 17)].

Bone transfer is the gradual shifting of a segment of bone from a healthy location into a place where bone loss occurs. A bone fragment is gradually moved using an external fixator under carefully controlled

Received: 04/08/2024
Accepted: 02/10/2024

mechanical conditions following a low-energy osteotomy or corticotomy beyond the diseased zone [18].

As the bone defect eventually closes, distraction osteogenesis produces new bones in the distraction gap, simultaneously restoring bone mass and skeletal continuity. Bone transport is defined by the limb's length remaining constant, as the amount of lengthening throughout the distraction gap is equal to the amount of shortening at the location of the bone defect [17]. Acute limb shortening in the area of the bone defect itself is an alternate Ilizarov technique to stop segmental bone loss [19]. It is possible to shorten this area abruptly, gradually, or both. Similar to the method for bone transport, the shortened limb is then extended to equalize limb lengths via bifocal osteosynthesis once more [9].

Limb length is then restored by distraction via a corticotomy at a different level after the external fixator applies immediate compression to perhaps promote a faster union at the location of the acute shortening [9].

Bone transport is generally utilized to treat patients with major bone abnormalities bigger than 4 cm, whereas acute shortening and subsequent lengthening are more commonly employed to treat instances with lesser bone deficits less than 3 cm [10]. Whichever option is chosen, complications are frequent and limb salvage treatment times are usually long.

This study aimed to assess the effectiveness of the Ilizarov external fixator in treating segmental tibial anomalies caused by different etiologies using specialized surgical techniques.

PATIENTS AND METHODS

This prospective study included a total of twenty-four patients with segmental tibial defects managed by Ilizarov external fixator, attending the Department of Orthopedic Surgery, Faculty of Medicine, Menoufia University Hospitals. This study was conducted between April 2021 and November 2023 with at least a year's follow-up were included in this prospective study.

.

Inclusion criteria: Patients with segmental tibial defects resulting from open fractures or following debridement of chronic osteomyelitis tibia are eligible to participate.

Exclusion criteria: pathological fractures (both benign and malignant tumors), patients deemed unsuitable for surgery, irreversible injury to the posterior tibial nerve, uncontrolled diabetic mellitus, and Charcot Arthropathy.

In This study every patient was treated using the Ilizarov fixator. All patients had their frames preassembled, and some patients had their assemblies modified during surgery.

A- Preoperative Evaluation:

Patient selection**:** The patient and his family were informed about the discomfort, difficulties, and approximate time required for the treatment in order to assess the patient's willingness to cooperate for a good outcome and the potential complications, such as skin, vascular, and neurogenic issues, and how they can be handled right away. This was done to achieve good results for a patient who had already undergone numerous surgical procedures, endured long hours of rehabilitation, was in pain, and was experiencing financial distress and family issues. In each instance, permission to operate was obtained. In one instance where angiography revealed substantial arterial damage, consent was obtained for potential future amputation if union was not achieved.

Radiological evaluation**:** Anteroposterior and lateral views of the affected tibia, stress views for stiff nonunion to demonstrate movement of the fracture site, and recent plain X-rays of the foot, femur, and pelvis to demonstrate related injuries were all taken. Nearby joints' malalignment was measured. One patient with an infected nonunion and ischemic limb underwent angiography. Three individuals with a history of vascular damage underwent a duplex study.

Frame configuration: Choosing the ring size. The rings were sized appropriately to give two fingerbreadths of space around the limb. Because dependent oedema moves posteriorly, the anterior soft tissue clearance may be lower than the posterior clearance. To cut down on surgical time, it was preferable to pre-assemble the frame before the procedure. Sensitivity test and preoperative culture.

Third-generation cephalosporins were given every eight hours for three doses in non-infected instances, and preoperative broad-spectrum antibiotics were given two hours prior to surgery based on the culture and sensitivity results in infected nonunion patients.

B- Operative technique:

In this series, general anesthesia, spinal analgesia, epidural anesthesia, or a combination of spinal and general anesthesia were employed. To reduce the tourniquet time and prevent nerve damage during wire insertion, the tourniquet was only used in situations of bone debridement and segment excision. It was then taken off before the frame was attached.

All infected instances underwent one stage debridement and Ilizarov application, except for two cases where the monolateral fixator was removed and radical debridement was performed, followed by the application of the Ilizarov fixator three weeks later. Each component is mounted independently and subsequently joined in cases with fixed abnormalities; this was done in two instances.

Depending on where the gap was, osteotomy was performed proximally in 18 patients, distally in 4 patients, or multifocal in 2 individuals **(Figure 1).**

Figure (1): Shape and configuration of the frames for nonunion with segment transport. A: Frame for segment transport by unifocal Osteotomy. B: Frame for bifocal distraction.

The plan is to simultaneously compress the gap segment and distract at the corticotomy site at a rate of 1 mm each day until the transported segment reaches the docking point, and then compress by ½ mm per week **(Figure 2)**. In one instance of a healed fibula, the limb was lengthened to the required length after the fibula was kept intact for a while and continued segment transport until it met at the docking location. A fibular osteotomy was then performed. Five patients had intraoperative acute shortening of 4 cm and resection of a portion of the fibula equal to the portion removed from the tibia. Postoperatively, the corticotomy site was lengthened and the gap was gradually compressed. In one patient, segment transport proceeded until the very end without fibular osteotomy despite a severe bone defect and an unbroken fibula.

Figure (2): Male patient 49 years old had grade IIIB open fracture tibia. (A) showing 13 cm of tibia were exposed without any soft tissue coverage to its antero-medial and lateral aspects. (B) Four months after trauma after excision of exposed necrotic bone with compression to minimize soft tissue defect followed by skin grafting with massive adhesions and flexion deformity. (C) X-ray showing severe deformity (shortening, translation and posterior angulation).

C- Post-operative management:

Every patient received routine wound and pin site care, and they were all given instructions on how to execute lengthening and/or distraction at the appropriate pace and rhythm for their individual circumstances. For non-infected patients, post-operative antibiotics (cephalosporins for 10 days) and for infected patients, repeated dressing changes until the incision heals completely. For six weeks, systemic antibiotics were prescribed for infected cases based on sensitivity and culture. To create some inherent stability, partial weight bearing was postponed for varying lengths of time (between two and eight weeks) until a meeting took place at the docking site. Range-of-motion exercises and gait training were part of the physiotherapy program that was started. In addition to passively stretching their toe joints, patients were taught to exercise their knees and ankles.

To evaluate alignment, bone contact, and subsequent callus formation, a follow-up x-ray was taken. There was a 7–10-day latency interval before distraction. As advised by Ilizarov, bone lengthening started at a rate of 1 mm per day divided into four sections. However, depending on the regenerate's quality, some adjustments were made, such as lowering the rate to 0.00 mm per day or using different compression and distraction techniques to enhance the regenerate's quality. In order to counteract bone resorption and promote union, wires are compressed by half a millimeter every week until they bow at the docking location.

D- Frame removal:

After loosening the connecting rods or the fixation bolts of the wires, the fixator was withdrawn when radiological evidence of union was found, when the patient was able to walk pain-free and felt the limb was solid, and when there was no mobility at the fracture site. Additionally, in cases of segment transport, anteroposterior and lateral view radiographs showed signs of consolidation of at least three cortices. It took an average of 181.5 days to reach full consolidation.

Under anesthesia, the frame is taken out, all pin sites are adequately debrided, covered with sterile dressings, and an above-knee cast is placed for four to six weeks. During the first two weeks of this time, weight bearing is permitted with caution, and during the remaining weeks, it is permitted without restriction.

Ethical approval:

Menoufia Faculty of Medicine Ethics Committee authorized this study. After receiving all the information, informed consent of all the participants or the participants' parents for young patients was obtained. The Helsinki Declaration was followed throughout the course of the investigation.

Statistical analysis

SPSS was used on an IBM-compatible computer to tabulate and analyze the data. Using descriptive statistics, the data was summarized using mean ± SD for quantitative variables and numbers (No) and percentages (%) for qualitative factors. The student's t-test, a parametric test for comparing two quantitative variables with normally distributed data, the Mann-Whitney test, a non-parametric test for comparing two quantitative variables with non-normally distributed data, and the Chi-squared test (χ^2), a parametric test for associations between qualitative variables, were all examples of analytical statistics. Using the Shapiro-Wilk test, which assumes normality at $P > 0.05$, the normality of quantitative data was evaluated. Statistical significance was considered as a P-value of less than 0.05.

RESULTS

Demographics and baseline characteristics

A total of 24 patients with segmental tibial bone defects were included in the study; twenty (83%) male and four (17%) female patients; their average age was 36.3±11.4 (range: 10-52) years. Ten (42%), and fourteen (58%) of the patients had the right side afflicted. Eight patients (33%) had segmental tibial defects because of fracture-nonunion, six patients (25%) had infected nonunion, and ten patients (41%), had open fractures. Fifteen patients (62.5%) were infection-free, whereas nine patients (37.5%) had a history of infection. Nonunion lasted an average of 6.2 months, with a range of 6–33 months. The average size of the defect was 6.2±2.6 cm, with a range of 3-16 cm (Table 1).

Table (1): Sociodemographic Data and incidence of complications

Variable		Number (Total=24)	Percent (%)
Age (year)	-I (less than 20) -II (20-40) -III (>40)	2 13 9	8.3% 54.2% 37.5%
Sex	-Male -Female	20 4	83.3% 16.7%
Smoking	-Yes -No	10 14	41.7% 58.3%
Other associated general diseases	-Normal -DM -Ankylosing spondylitis -Cardiac	18 3 1 2	75% 12.5% 4.2% 8.3%
Cause	-Fracture non-union -Infected non-union -Open fracture	8 6 10	33.3% 25% 41.7%
Type of fracture	-Open -Closed	9 15	37.5% 62.5%
Skin condition	-Sinus - Skin loss followed by graft -Flap	6 5 1	25% 20.8% 4.2%
Site of non-union	-Upper -Middle -Lower	8 3 13	33.3% 12.5% 54.2%
Infection	-Yes -No	9 15	37.5% 62.5%
Neurovascular Normal	-Normal -Sciatic palsy -Anterior tibia artery defect	19 3 2	79.2% 12.5% 8.3%
Complications	-No complications -Severe edema and pin tract infection -Mechanical block then amputation -Equines foot -Sloughed knee graft -Over lengthened -Weak regenerate	9 5 1 3 2 2 2	37.5% 20.8% 4.2% 12.5% 8.3% 8.3% 8.3%
Leg length discrepancy	-No -Yes	15 9	62.5% 37.5%
Outcome	-Union -Soft knee -Amputation -Insensitive limb -Equines gait	14 3 2 1 4	58.3% 12.5% 8.3% 4.2% 16.7%

Functional and radiological outcomes

Five criteria are used to determine the functional results: a noticeable limp, stiffness in the ankle or knee, soft-tissue sympathetic dystrophy, and pain keeping the patient from sleeping and inactivity.

None of the other four criteria applied, and the patient had excellent results when active. If the patient was active and one or two of the other criteria applied, it was a good outcome. A fair outcome would be if three or four of the other criteria applied and the patient was active. Bad outcome: if the patient did not engage in any activity, even if other conditions were met. Twenty patients (73.3%) had satisfactory functional results, whereas 14 patients (58.3%) had excellent results, and 6 patients (25%) had good results. Four patients (16.7%) had unsatisfactory outcomes, three patients (12.5%) had fair results, and one patient (4.2%) had poor results.

As per the ASAMI protocol, a good radiological bone result was defined as union without the need for a bone graft, leg-length inequality of less than 2.5 centimeters, no infection, and deformity of less than 7 degrees. A good result was defined as union plus any two of the other three criteria. union and one of the other criteria, a fair outcome. a subpar outcome, as non-union or refracture, or as union but lacking any of the other three requirements needed for a great outcome. 21 patients (87.5%) had satisfactory radiological results, 13 patients (54.2%) had excellent outcomes, and 8 patients (33.3%) had good results. In three patients (12.5%), the findings were unsatisfactory.

Table (2): Functional and Radiological Results

		No	%
Clinical Outcomes	**Satisfactory**		
	Excellent	14	58.3%
	Good	6	25%
	Unsatisfactory		
	Fair	3	12.5%
	Poor	1	4.2%
	Total	24	100%
Radiological Outcomes (ASAMI Score)	**Satisfactory**		
	Excellent	13	54.2%
	Good	8	33.3%
	Unsatisfactory		
	Poor	3	12.5%
	Total	24	100%

The difference between the functional and radiological bone outcomes was statistically significant (p-value = 0.016). Thirteen patients had outstanding radiological bone findings; eleven of these individuals had excellent functional results, two had good results, and none had fair or poor functional results (Table 3). Nine patients with closed fractures had excellent bone union, but only four patients with open fractures had excellent bone union. This difference was statistically significant (p-value = 0.016) (Table 3). Smokers and non-smokers did not differ statistically significantly in terms of bone union (p-value=0.831).

Table (3): Relation between Functional Result regarding Bone union, Type of Fracture and Duration of Nonunion

Functional results	Bone union						test	P- value
	Excellent (n=13)		Good (n=8)		Poor (n=3)			
	No	%	No	%	No	%		
Excellent	11	84.6	3	37.5	0	0	X 15.61	0.016*
Good	2	15.4	3	37.5	1	33.3		
Fair	0	0	2	25	1	33.3		
Poor	0	0	0	0	1	33.3		
Type of the fracture								
Open	4	44.4	3	33.3	2	22.2	X 15.61	0.016*
Closed	9	60	5	33.3	1	6.7		
Functional results	**Duration of non -union (Mean ±SD)**							
Excellent	18.4 ±8.78						K 8.205	0.046*
Good	12.16 ±4.35							
Fair	8.3± 2.08							
Poor	30 ± -							

Regarding bone findings, there was no statistically significant difference between those who were infected and those who were not (p-value=0.615). Six patients with a history of infection had good results, whereas seven individuals without an infection had outstanding results. While the mean consolidation time was 181.5± 46.3 days with a range of (120-170) days, the mean lengthening time was 105.5± 32.3 days with a range of 60-160 days (Table 4).

Table (4): Evaluation of patients during treatment period

Variable	Mean ± SD (Range)
Duration of non-union (in months)	16.1± 8.5 (6-33) month
Duration of non-union (in months)	6.2±2.6 (3-16) cm
Lengthening time (in days)	105.5±32.3 (Range, 60-160) days
Consolidation time (in days)	181.5± 46.3 (Range, 120-270) days

Complications:

Among them are 21 patients (87.5%) who experienced pin tract infections of varying severity. Pin-site treatment with systemic and local antibiotics was successful for every patient. Ten patients (41.66%) had their nuts loosen during follow-up, and retightening was performed at the outpatient clinic. Three patients (12.5%) had their wire fixation bolts loosened during follow-up, and re-tensioning was performed for them in the outpatient clinic. Six patients (25%) experienced delayed consolidation of the regenerate, for which additional compression and distraction were performed until final consolidation. Six patients (25%) developed equinus deformity (30 degrees); four of these patients recovered with manipulation under anesthesia (MUA) and casting followed by physiotherapy, and two of these patients were treated with three-level percutaneous Achilles tendon lengthening following frame removal and prior to casting. Four patients (16.66%) experienced segment deviation, for which an Ilizarov adjustment was performed. One patient (4.16%) who failed to distract during the early distraction phase had an incomplete corticotomy. Under anesthesia, a re-corticotomy was performed.

Three patients (12.5%) developed stiff knees, which improved to a degree of roughly 30 degrees of flexion after receiving MUA and physiotherapy. Amputation was performed on one patient (4.16%) who declined to proceed after experiencing a mechanical block during distraction (Table 1).

Figure (3): Clinical and radiological outcomes (A) Postoperative acute correction of the deformity with shortening and antegrade intramedullary Rush pin was applied followed by Ilizarov Fixation and distal tibial corticotomy for segment transfer, (B) Segment transfer 16 cm, (C) Clinical leg length discrepancy (D) Final consolidated regenerate (E) Healed Skin and restored leg length .

DISCUSSION

The traditional use of autogenous grafts, allografts, graft substitutes, vascularized fibular grafts, and the administration of anabolic medications are among the several techniques available for treating segmental tibial abnormalities. However, each of these approaches has a unique set of drawbacks. Multi-drug-resistant infections, joint stiffness in the surrounding areas, and soft tissue loss with many sinuses were among the problems associated with non-union tibias with underlying illness [20, 21].

Because it simultaneously addresses issues like soft tissue loss, joint contractures, angular deformities, osteomyelitis, osteoporosis, complex deformities with length disparities, and resistant diseases that usually require a drastic approach to the infected bone and soft tissue, as well as the use of stable support to promote soft tissue healing and union, bone transport has demonstrated efficacy. In these situations, a segment can be gradually transported to fill the deficiency or the defect can be sharply shortened [20, 21].

In terms of radiological results, our study showed adequate radiological bone union in 87.5% of the patients (54.2% excellent, 33.3% good) based on the ASAMI scoring system. This success rate is like that found in other studies. For example, in their series of 32 patients treated with the Ilizarov procedure for tibial abnormalities, **Paley *et al.*** [22] found a 77% union rate (24 individuals).

In 2024, Chand *et al.* [23] found that eight instances (61.54%) had a great primary union, while five patients (38.46%) needed bone grafting at the docking site, with four patients having good results and one having fair results.

In 2009, Öztürkmen *et al.* [24] investigated the experience with segmental tibial fractures and assessed the outcomes of acute application of the Ilizarov external fixator. In terms of bone assessment, they found that out of 24 patients with segmental tibial fractures, 20 (83.33%) had outstanding results and 4 had good results. In a study performed by **Tranquilli *et al.*** [25] in Italy in 2000 on 20 patients with non-union of the tibia, the result was union in all the patients, with the mean time of union being 4.5 months.

Our study's functional outcomes showed promising results as well, with 83.3% of patients obtaining satisfactory improvements (58.3% outstanding, 25% good). These findings are in line with those of **Aktuglu *et al.*** [26] who discovered that 82.6% of 27 publications involving 619 patients had excellent and good functional results, and 12.6% had fair results while 4.5% had poor functional results. According to **Chand *et al.*** [23]**,** out of 13 patients treated for significant tibial bone abnormalities, six (46%) and seven (54%), respectively, had excellent functional outcomes. According to **Yin *et al.*** [27]**,** 76% of the functional findings were excellent or good.

It's interesting to note that our research revealed a substantial correlation (p = 0.016) between bone and functional results, indicating that excellent functional outcomes depend on attaining good bone union. Previous investigations have observed this link, including one **by El-Rosasy** [19], who highlighted the significance of bone quality in influencing functional outcomes.

Infected and non-infected cases did not significantly differ in their ability to achieve a radiographic bone union (p = 0.615), according to our study. This is a little unexpected because numerous studies have shown that infected cases have worse outcomes, such as the one by **Yin *et al.*** [27]**.** Due to the Ilizarov method's capacity to treat infection through debridement and progressive transfer, our findings imply that it may be just as successful in treating infected and non-infected tibial abnormalities.

There was no discernible correlation between smoking and bone outcomes (p = 0.831). This contrasted with other research, such as that conducted by **Patel *et al.*** [28], which indicated that smoking was a risk factor for bone repair. Further research with a bigger cohort may be necessary since our findings could be influenced by other confounding factors or the relatively limited sample size.

It's interesting to note that our research revealed a significant correlation (p = 0.046) between the length of non-union status and functional outcomes, with longer non-union status being linked to higher functional outcomes. This discovery defies most reports in literature and is paradoxical. **Xu *et al.*** [29] discovered, for instance, that longer periods of non-unionization were linked to worse results. More research is required to fully understand the relationship between selection bias and other confounding factors, which could be the cause of our results.

In our study, the most frequent complications were severe edema and pin tract infection (20.8%), with an overall complication incidence of 62.5%. This rate of complications falls within the range that has been documented in the literature. For example**, Feng *et al.*** [30] found that all 199 patients who were followed up with for 12–40 months (average of 23.5 months) experienced bone repair. On average, each patient experienced 0.48 major complications and 1.04 minor difficulties out of 310 total issues. When the Ilizarov bone transport technique was used to treat tibial bone abnormalities, the top three problems were delayed union in 50 instances (25.13%), axial deviation in 86 cases (43.2%), and pin tract infection in 48 cases (61.3%).

According to **Ghorab *et al.*** [31] external fixation has also been linked to several problems, the majority of which were mild. Most external fixation-related problems are caused by pin tract disorders. Even though most patients only had minor, superficial illness, it raised the possibility of wire loosening and resulted in frame instability because of the weight supported by the external frame. Of the 44 patients (31%) who required grafting to achieve full union, 14 had delayed union of the docking site.

According to **Yin *et al.*** **(32)** each patient had an average of 1.22 problems. Both amputation and refracture rates were 4%. Knee stiffness, infection recurrence, and malunion rates were 7%, 5%, and 12%, respectively. Significant statistical heterogeneity was discovered for the most frequent complication when employing Ilizarov procedures, which is pin-track infection.

According to **Öztürkmen *et al.*** **(24)** there were no refractures following the removal of the frame. Thirteen (54%) of the twenty-four individuals had pin-tract infections. but in our study, it happened to 5 patients (20%). No cases of persistent osteomyelitis brought on by pintract infection were reported. The distal fractures took an average of 39.8 weeks (range 12-80) while the proximal fractures took an average of 36.4 weeks (range 10-78) to unite (p>0.05). Consolidation and callus developed earlier posterolaterally. No implant failures occurred.

Green **(33)** discovered that in six (42%) of their 14 instances, grafting was required. Grafting the docking site was suggested by **Song *et al.*** **(17)** as a way to shorten the healing period.
Two patients (8%) with severe (16, 17 cm) defects had interposed soft tissue obstructing transport, according to **Paley *et al.*** **(9)**. Four patients underwent soft tissue interposition and transport over a wire inserted into their intramedullary canals to avoid malalignment. In our study, 14 patients (58%) needed bone grafting at the docking location.

As noted by **Lasanianos *et al.*** **(34),** who stressed that although difficulties are prevalent with the Ilizarov procedure, they are typically resolvable without compromising the final outcome, it is worth emphasizing that the majority of complications in our study were small and treatable.

In our study, 75% of patients reported being extremely or fairly satisfied with the entire process, indicating generally excellent patient satisfaction .

This degree of satisfaction is like that described by **Krappinger *et al.*** **(35),** who used the Ilizarov approach for tibial deformities and found that patients were satisfied with the overall outcome and the lower extremity's function.

Twenty-eight patients, ages 18 to 74, were treated by **Dendrinos *et al.*** **(12)** using distraction osteogenesis for pathological non-union of the tibia. He found that 17 patients (64.3%) had satisfactory functional results, and 21 patients (70.8%) had satisfactory results.

Interestingly, 83.3% of our patients said they would have the surgery again if it were recommended. This high degree of acceptance highlights the Ilizarov method's efficacy from the patient's point of view, even despite the drawn-out course of treatment and possible side effects.

CONCLUSION

It could be concluded that segmental tibial defects of different etiologies could be effectively managed with the Ilizarov external fixator. In most cases, the method produces good to exceptional bone and functional results, with a high patient satisfaction rate and a controlled complication profile. The Ilizarov technique is still a useful tool in the orthopedic surgeon's toolbox for treating complex tibial abnormalities, despite ongoing difficulties, especially regarding treatment duration and complication management.

Conflict of interest: None.
Financial disclosures: None.

REFERENCES

1. **Aronson J, Johnson E, Harp J (1989):** Local Bone Transportation for Treatment of Intercalary Defects by the Ilizarov Technique. Clinical Orthopaedics and Related Research, 243:71-9.
2. **Cattaneo R, Catagni M, Johnson E (1992):** The Treatment of Infected Nonunions and Segmental Defects of the Tibia by the Methods of Ilizarov. Clinical Orthopaedics and Related Research, 80:143-52.
3. **Aronson J (1997):** Current Concepts Review - Limb-Lengthening, Skeletal Reconstruction, and Bone Transport with the Ilizarov Method*. The Journal of Bone & Amp; Joint Surgery, 79(8):1243-58.
4. **Iii G, Zorn K (1994):** Segmental Tibia1 Defects Comparing Conventional and Ilizarov Methodologies. Clinical Orthopaedics and Related Research, 301:118-23.
5. **Christian E, Bosse M, Robb G (1989):** Reconstruction of large diaphyseal defects, without free fibular transfer, in Grade-IIIB tibial fractures. The Journal of Bone & Amp; Joint Surgery, 71(7):994-1004.
6. **Papineau L, Alfageme A, Dalcourt J *et al.* (1979):** Chronic Osteomyelitis: Open Excision and Grafting After Saucerization. International Orthopaedics, 3(3): 165–176.
7. **Masquelet A, Begue T (2010):** The concept of induced membrane for reconstruction of long bone defects. Orthop Clin North Am., 41(1):27-37.
8. **Khaled A, El-Gebaly O, El-Rosasy M (2022):** Masquelet-Ilizarov technique for the management of bone loss post debridement of infected tibial nonunion. International Orthopaedics, 46(9):1937-44.
9. **Paley D, Catagni M, Argnani F *et al.* (1989):** Ilizarov Treatment of Tibial Nonunions With Bone Loss. Clinical Orthopaedics and Related Research, 241:146-65.
10. **Paley D, Maar D (2000):** Ilizarov Bone Transport Treatment for Tibial Defects. Journal of Orthopaedic Trauma, 14(2):76-85.
11. **Dagher F, Roukoz S (1991):** Compound tibial fractures with bone loss treated by the Ilizarov technique. The Journal of Bone and Joint Surgery, 73-B(2):316-21.
12. **Dendrinos G, Kontos S, Lyritsis E (1995):** Use of the Ilizarov technique for treatment of non-union of the tibia associated with infection. The Journal of Bone &

Amp; Joint Surgery, 77(6):835-46.

13. **Lowenberg D, Feibel R, Louie K *et al.* (1996):** Combined Muscle Flap and Ilizarov Reconstruction for Bone and Soft Tissue Defects. Clinical Orthopaedics and Related Research, 332: 37-51.
14. **Robert Rozbruch S, Weitzman A, Tracey Watson J *et al.* (2006):** Simultaneous Treatment of Tibial Bone and Soft-tissue Defects With the Ilizarov Method. Journal of Orthopaedic Trauma, 20(3):194-202.
15. **Yushan M, Abulaiti A, Maimaiti X *et al.* (2022):** Tetrafocal (three osteotomies) and pentafocal (four osteotomies) bone transport using Ilizarov technique in the treatment of distal tibial defect—preliminary outcomes of 12 cases and a description of the surgical technique. Injury, 53(8):2880-87.
16. **Saleh M, Rees A (1995):** Bifocal surgery for deformity and bone loss after lower-limb fractures. Comparison of bone-transport and compression-distraction methods. The Journal of Bone and Joint Surgery, 77-B(3):429-34.
17. **Song H, Cho S, Koo K *et al.* (1998):** Tibial bone defects treated by internal bone transport using the Ilizarov method. Int Orthop., 22: 293-97.
18. **Paley D, Tetsworth K (1991):** Percutaneous Osteotomies Osteotome and Gigli Saw Techniques. Orthopedic Clinics of North America, 22(4):613-24.
19. **El-Rosasy M (2007):** Acute shortening and re-lengthening in the management of bone and soft-tissue loss in complicated fractures of the tibia. The Journal of Bone and Joint Surgery, 89-B(1): 80-88.
20. **Ferretti A (1994):** Small bone fixator. In: Bianchi Maiocchi A (ed.,): Advances in Ilizarov apparatus assembly. Milan, Italy, Medicalplastic Srl., pp. 134-139.
21. **Catagni M, Malzev V, Kirienko A *et al.* (1994):** Pseudarthroses of the femur. In: Bianchi-Maiocchi A, (editor), Advances in Ilizarov apparatus assembly. Milan: Medicalplastic Srl., pp. 70-4.
22. **Paley D, Herzenberg J, Tetsworth K *et al.* (1994):** Deformity Planning for Frontal and Sagittal Plane Corrective Osteotomies. Orthopedic Clinics of North America, 25(3):425-65.
23. **Chand B, Rajbhandari A, Banskota A *et al.* (2014):** Open segmental tibial bone defects treated with Ilizarov frame: a radiological and functional outcome study with average ten year follow-up. International Orthopaedics, 48(10): 2519-23.
24. **Öztürkmen Y, Karamehmetoğlu M, Karadeniz H *et al.* (2009):** Acute treatment of segmental tibial fractures with the Ilizarov method. Injury, 40(3):321-6.
25. **Tranquilli L, Merolli A, Perrone V *et al.* (2000):** The effectiveness of the circular external fixator in the treatment of post-traumatic of the tibia nonunion. Chir Organi Mov., 85(3):235-42.
26. **Aktuglu K, Erol K, Vahabi A *et al.* (2019):** Ilizarov bone transport and treatment of critical-sized tibial bone defects: a narrative review. J Orthop Traumatol., 20(1):22. doi: 10.1186/s10195-019-0527-1.
27. **Yin P, Zhang Q, Mao Z *et al.* (2014):** The treatment of infected tibial nonunion by bone transport using the Ilizarov external fixator and a systematic review of infected tibial nonunion treated by Ilizarov methods. Acta Orthop Belg., 80(3):426-35.
28. **Patel R, Wilson R, Patel P *et al.* (2013):** The effect of smoking on bone healing: A systematic review. Bone Joint Res., 2(6):102-11.
29. **Xu K, Fu X, Li Y *et al.* (2013):** A treatment for large defects of the tibia caused by infected nonunion: Ilizarov method with bone segment extension. Irish Journal of Medical Science, 183(3): 423-28.
30. **Feng D, Zhang Y, Jia H *et al.* (2023):** Complications analysis of Ilizarov bone transport technique in the treatment of tibial bone defects-a retrospective study of 199 cases. BMC Musculoskelet Disord., 24(1):864. doi: 10.1186/s12891-023-06955-0.
31. **Ghorab A, Elnegehy A, Salama A *et al.* (2024):** Managment of tibial bone defects by segmental bone transport using ilizarov technique. Zagazig University Medical Journal, 30(2): 552-560.
32. **Yin P, Ji Q, Li T *et al.* (2015):** A Systematic Review and Meta-Analysis of Ilizarov Methods in the Treatment of Infected Nonunion of Tibia and Femur. PLoS One, 10(11):e0141973. doi: 10.1371/journal.pone.0141973.
33. **Green S (1994):** Skeletal Defects A Comparison of Bone Grafting and Bone Transport for Segmental Skeletal Defects. Clinical Orthopaedics and Related Research, 301:111-17.
34. **Lasanianos N, Kanakaris N, Giannoudis P (2010):** Current management of long bone large segmental defects. Orthopaedics and Trauma, 24(2):149-63.
35. **Krappinger D, Irenberger A, Zegg M *et al.* (2013):** Treatment of large posttraumatic tibial bone defects using the Ilizarov method: a subjective outcome assessment. Archives of Orthopaedic and Trauma Surgery, 133(6):789-95.