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ORIGINAL ARTICLE:

Managment of Tibial Bone Defects by Segmental Bone Transport Using Ilizarov Technique

Ahmed Salah Ali Awad Ghorab[1], Alaa Ahmed Mostafa Elngehy[1], Adel Mohamad Salama[1], Hosam Eldien Fekry Abdel Aziz[1]*

[1] Department of Orthopaedic Surgery, Faculty of Medicine, Zagazig University, Zagazig, Egypt

*** Corresponding author:**
Ahmed Salah Ali Awad Ghorab
Department of Orthopaedic Surgery, Faculty of Medicine, Zagazig University, Zagazig, Egypt

E-mail:
ahmed.ghorab.2021@gmail.com

ABSTRACT

Background: A tibial defect greater than 4 cm is a common clinical entity, particularly among populations with sever acute trauma, infection sequalae, congenital pseudoarthrosis tibia, and following tumor resection. Segmental bone transport by using an Ilizarov external fixator has become the treatment of choice. The aim of this prospective study was to evaluate the results of using the Ilizarov fixator in the treatment of tibial defects, its advantages, and its complications.

Methods: Our prospective study was conducted involving 44 cases with tibial defects (from 4 to 15 cm) of different causes. All patients are treated by segmental bone transport using an Ilizarov external fixator. All patients were operated on at Zagazig University Hospitals.

Results: 44 patients were followed up from March 2018 to December 2021. Infection was eradicated in all cases, and union was achieved in all cases, with no cases of limb amputation. The infection was eradicated in all the infected cases without the need for prolonged antibiotics and without reactivation throughout the period of follow-up. The union was achieved in all cases.

Conclusions: Distraction histogenesis is a good solution for segmental tibial defects. The Ilizarov technique is complicated and requires a great deal of expertise to perform successfully. Ilizarov's bone defect reconstruction was less expensive and easier to perform. Bone graft at the docking site may be needed to enhance the union and shorten the time in fixation.

Keywords: Bone transport, Bone lengthening, Ilizarov, Distraction osteogenesis

INTRODUCTION

Bone is among the very few tissues in the human body that possess the intrinsic capacity to heal spontaneously following injury. However, beyond a certain critical size, defects cannot heal by themselves; outside intervention is required [1]. Numerous techniques were available for the management of these defects, including the gold standard of autogenous grafts, allografts, graft substitutes, vascularized fibular grafts, and the technique of administration of anabolic agents. All these techniques, however, do have limitations [2].

Troubles associated with diseased non-union tibias included soft tissue loss with multiple sinuses, osteomyelitis, osteoporosis, complex deformities with length inequality, stiffness of the adjacent joints, and multi-drug-resistant disease [3]. These factors complicate the recovery. Even after prolonged, repeated surgeries to correct this trouble, the outcome was unsure, and amputation might be the only alternative left. Hence, the non-union of long bones associated with disease presented a formidable challenge to the orthopedic surgeon [3]. Transport has been used with good success, as it simultaneously addresses issues of shortening and angular deformity as well as soft tissue loss, join contractures [4], or resistant diseases that usually require a radical of the septic bone and soft tissue in addition to the application of stable to enhance soft tissue healing and union. Defects in this situation could be filled up either by acutely shortening or gradually transporting a segment to fill in the defect [5].

In the case of defects with this technique, a cortical was made through a healthy segment at some distance from the defect site. Components of the frame were attached with wires to the segment between the defects. Thereafter, steady traction was applied to the intercalary segment to elongate the coticotomy region while closing the original skeletal defect at the same time [6, 7]. A new formation within the distraction gap forms according to the tension-stress critical. With this method, the length was maintained, the deformity

was corrected, the shortening was gradually overcome, and the defect was eliminated [8].
The aim of this prospective study was to evaluate the results of using the Ilizarov fixator in the treatment of tibial defects, its advantages, and its complications.

METHODS

This was a prospective study of 44 cases with tibial defects treated using an external Ilizarov fixator at Zagazig University Hospital from March 2018 to December 2021. The ages ranged from 3 to 65 years, with a mean age of 34 years. Written informed consent was obtained from all participants, and the study was approved by the research ethics committee of the Faculty of Medicine at Zagazig University. The study was done according to The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.
The patients enrolled in this study were cases of diseased ununited tibia with a large sequestrum, cases of ununited tibia with large defects, and cases of traumatic tibial defects. Also, technically fit cases, such as cases with tibial defects after excision of pathologic disease, e.g., tumors and pseudoarthrosis.
In this study, the exclusion criteria were small tibial defects less than 2cm and traumatic tibias without defects. Technically unfit cases were also excluded, such as cases with severe damage to the tibial nerve, cases that could be safely treated by the simple method of O.R.I.F. grafting, and cases with mental disease. All cases had been evaluated preoperatively using plain X-ray A.P. and lateral films showing the above and below joins.

Operative techniques

Anesthesia: The procedure had been performed under spinal or epidural anesthesia and general anesthesia (pseudoarthrosis tibia).

Position: The case was in the supine position on a radiolucent table, and the image intensifier was draped, positioned for easy entry and withdrawal.

Transport with the circular external: The assembly consisted of 3 to 5 rings: 2 proximal rings, 1 for transport, and 2 distal rings. Two Kirschner wires had been inserted, tensioned for each of the proximal and distal rings. It was important to include the foot in the frame in large distal to proximal transport (more than 5 cm) to avoid equinus deformity. They had performed multiple drillings after the wire had been applied. performed This procedure is known as "closed osteoclasis," whereby wires were placed around the bone and attached to the frame so that tensioning of the wires would produce a three-point bending force, fracturing the bone. Another technique involves transecting approximately two-thirds of the cortex and completing the osteoclasis produced by rotating the external rings in opposite directions. Others had described inserting the osteotome into the site and rotating it 90° until the remaining cortex was reached. Other techniques described include a complete transverse osteotomy to ensure division of the entire cross section or connecting multiple drill holes with an osteotome. Transport commenced seven days later at an average rate of 1/4 mm every six hours. Transport with a circular external might be associated with transport over a wire placed in the intramedullary canal that prevents malalignment and soft tissue interposition**.** The distraction continued until the defect compensated. The docking site union had been assessed clinically and radiologically by stress testing, along with radiologic cortical continuity. Consolidation of the regeneration was the determining factor in the removal of the fixator.
A post-operative plane x-ray had been done. Starting from the first postoperative day, cases allowed non-weight-bearing ambulation on crutches with full range of motion of the knee and ankle. Straight leg raising, quadriceps strengthening, ankle dorsiflexors, and plantar flexor strengthening exercises had been encouraged. Cases were discharged on the second postoperative day after careful instruction about daily pin site care.
The clinical picture on admission and application of uniplanar fixator were illustrated in **Figure 1A**. The immediate post-operative clinical and radiological pictures were demonstrated in **Figure 1B.**

Grafting: Radiological follow-up of the cases for 3 months after transport had finished (**Figure 2A**). If docking site union didn't occur, grafting was a must. It had done so in only 14 cases out of 44. It had done so due to inadequate reshaping of the ends, which made compression of the site not uniform in all the cross sections of the nonunion site. In diseased cases, it had done so to accelerate union and shorten the already long duration of treatment. Post-removal radiological follow-up illustrated in **Figure 2B.**

Statistical analysis

Data collected throughout history, basic clinical examination, laboratory investigations, and outcome measures were coded, entered, and analyzed using Microsoft Excel software. The data was then imported into Statistical Package for the Social Sciences (SPSS version 25.0) software for analysis. The data had been tested for normal distribution using the Shapiro-Walk test. Qualitative data was represented as frequencies and relative percentages. The Chi square test ($\chi 2$)

was used to calculate the relationship between qualitative variables as indicated. Quantitative data is expressed as the mean ± SD (Standard deviation) for parametric data and the median for non-parametric data. An independent T test was used to calculate the difference between quantitative variables in two groups for parametric variables and a Mann-Whitney test for non-parametric variables. A p-value of < 0.05 was considered statistically significant.

RESULTS

All demographic and clinical data are presented in **Table 1**. The age of the cases ranged from 3 to 65, with a mean of 34 years. Half of them were between 20 and 40 years old. More than half of them (56.8%) were male. The defect was in the lower third in 24 cases, in the middle third in 10 cases, and in the upper third in 10 cases. As regards etiology, more than half of them (61.4%) were traumatized. Regarding the length of the defect after debridement, the majority (63.6%) of them had a defect of ≤ 6 cm. Most of them (81.1%) had open fractures. Forty-five percent of cases had active infections, and 31.8% had latent infections.

Table 2 presents the operative data. In 68.2% of cases, the foot was not included in the frame. Regarding the site of corticotomy, 68.2% of cases had a proximal site of corticotomy, and 31.8% of them had a distal site of corticotomy. Nearly 88% of cases did not use an IM nail during transport. A bone graft was needed in 31.8% of cases.

Regarding the improvement, cases aged from 20 to 40 years improved critically better than ≤ 20 years or > 40 years old (p-value < 0.05). The females improved critically better than the males (p-value < 0.05). The length of ≤ 6 cm improved critically better than >6 cm (p-value < 0.05). There was a critical result regarding type, with a preference for closed cases over open (p-value < 0.05). There was a critical result as regards the etiology, with preference for traumatic cases over chronic osteomyelitis, congenital pseudoarthrosis (p-value < 0.05). There was a critical result regarding the site of the defect, with preference for lower defect cases over upper or middle defect cases (p-value < 0.05). There was a critical result about the state of disease, with a preference for no disease over latent or active infection (p-value < 0.05). There was a critical result regarding direction of transport, with preference for proximal to distal rather than distal to proximal (p-value < 0.05)**.** There was a critical difference in result about graft with preference to no graft versus with (p-value < 0.05).

The complications following tibial segment bone transport are presented in **Table 3**. Pin tract disease was the most common complication. Regarding limb length discrepancies, **Table 4** shows that 9.1% of cases had a >2.5 cm discrepancy. The duration of treatment after the operation is presented in **Table 5**.

Table 1: Demographic and clinical data of the cases

Parameter	**Cases (No.=44)**	
	Number	**Percentage**
Age		
Less than 20 years	13	29.6%
20-40 years	22	50%
More than 40 years	9	20.4%
Sex		
Males	25	56.8%
Females	19	43.2
Level of the defect after debridement		
Upper third	10	22.7%
Middle third	10	22.7%
Lower third	24	54.6%
Etiology of the bone defects		
Acute trauma	27	61.4%
Trauma sequalae (Infection)	10	22.7%
Congenital pseudoarthrosis	4	9.1%
Tumors resection	3	6.8 %
Acute trauma	27	61.4%
Length of the defect after debridement		
≤ 6 cm	28	63.6%

Parameter	Cases (No.=44)	
	Number	Percentage
> 6 cm	16	36.4%
Incidence of infection		
Active infection	20	45.5%
Latent infection	14	31.8%
No infection	10	22.7%
Type of fracture		
Open	30	81.1%
Closed	7	18.9%

Table 2: Operative data

Parameters	Cases (No.=44)	
	Number	Percentage
Inclusion of foot in the frame		
Yes	14	31.8%
No	30	68.2%
Site of the corticotomy		
Proximal	30	68.2%
Distal	14	31.8%
Use of IM nail during transport		
Yes	5	11.4%
No	39	88.6%
Need for bone graft		
Bone graft	14	31.8%
No bone graft	30	68.2%

Table 3: Complication following tibial segment bone transport.

Complications	Cases (No.=44)	
	Number	Percentage
Pin tract disease	34	77.7%
Refracture	6	13.6%
LLD	20	45.5%
Nonunion	14	31.8%
Malunion	4	9.1%
Compartment syndrome	2	4.5%
Skin impingement at docking site	2	4.5%
Foot equinus	2	4.5%
Impingement	2	4.5%
Pin tract disease	34	77.7%
Refracture	6	13.6%

Table 4: Limb length discrepancy

L-L discrepancy	Cases (No.=44)	
	Number	Percentage
≤2.5 cm	40	90.9%
>2.5 cm	4	9.1%

Table 5: Duration of Treatment

Duration of treatment	Cases (No.=44)	
	Number	Percentage
6 months	7	15.9%
7 months	8	18.2%
8 months	7	15.9%
9 months	6	13.6%
12months	6	13.6%
14 months	4	9.1%

Duration of treatment	Cases (No.=44)	
	Number	Percentage
16 months	3	6.8%
20 months	2	4.6%
24 months	1	2.3%

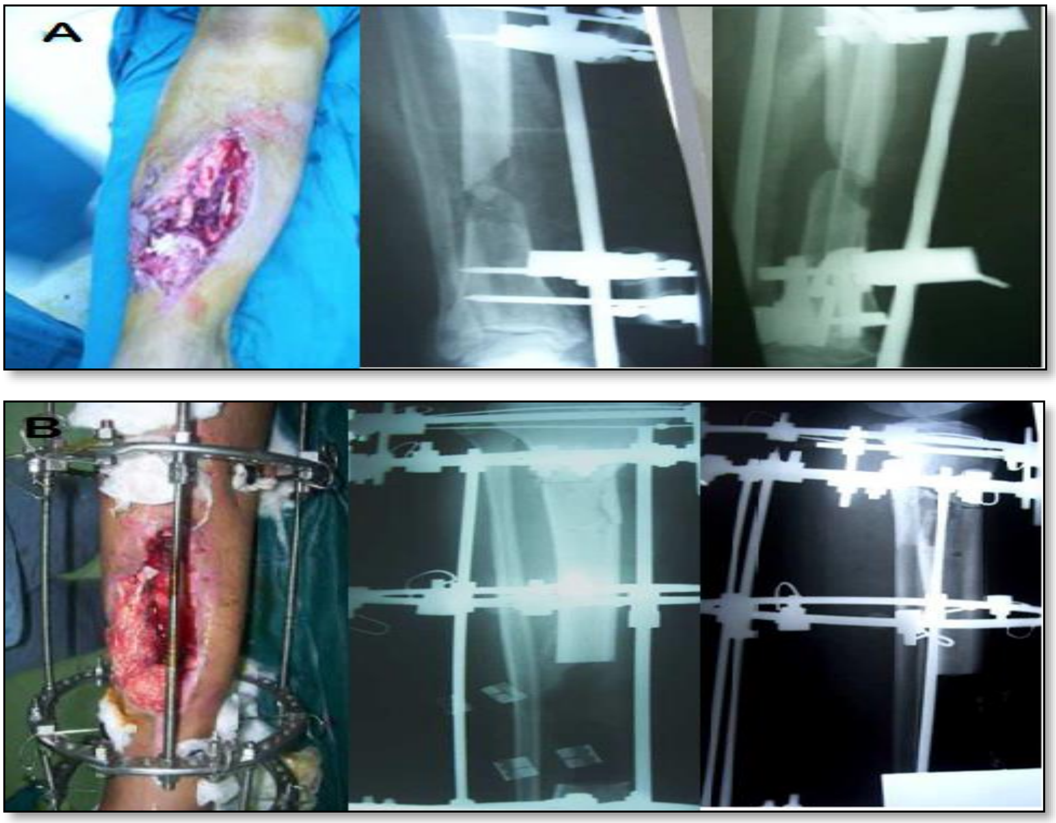

Figure 1: (A) Clinical picture on admission and application of uniplanar fixator, (B) Immediate post-operative clinical and radiological pictures.

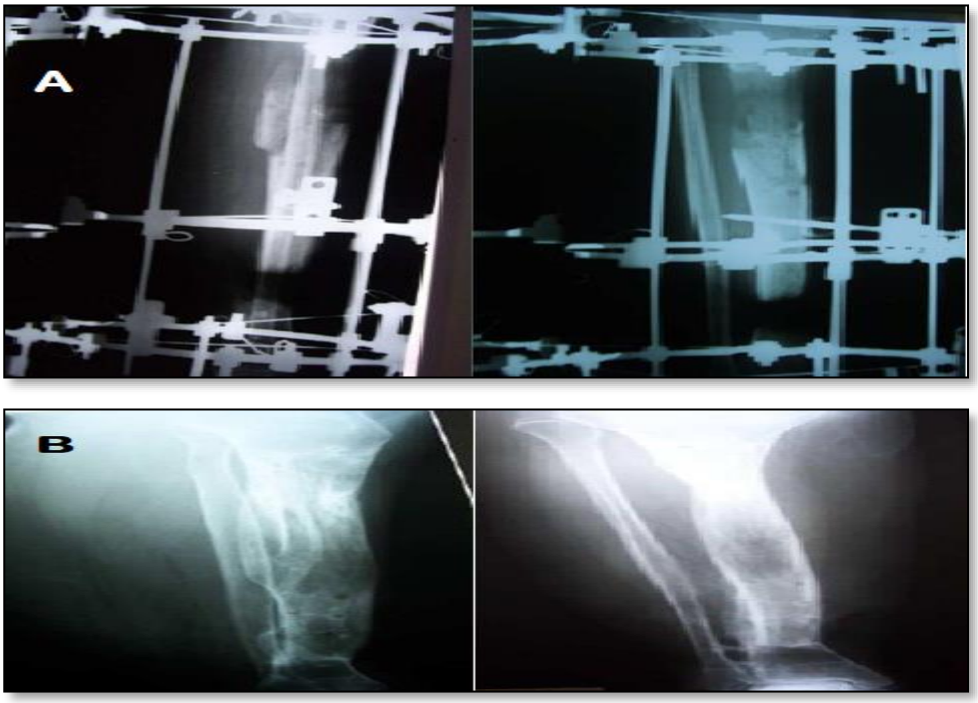

Figure 2: (A) Follow up after 3 months, (B) Post-removal radiological follow-up.

DISCUSSION

Many methods have been employed to treat tibial defects, e.g., radical, local flaps, muscle flaps, grafting, tibiofibular synostosis, allograft, fibrin mixed with antibiotics, antibiotic beads, microvascular flaps, and vascularized transplants.

All had improved results, but none had been able to fully solve this clinical situation [9].
The ring gives the option of compression, distraction, or transport, which is critical in the case of diseased non-union of the tibia where other types have failed [10]. Weight bearing and the functioning of the joints while on the bike had an advantage that could not be matched by any other technique. The apparatus was axially elastic, and as the weight-bearing forces were directly applied to the ends, maintaining the weight-bearing function of the extremity became one of the prerequisites for the success of the method [10].
The cyclic axial telescoping mobility, not rigidity, at the non-union site was an important requirement for the formation of a reparative callus. Experimentally, it was shown that when gradual tension stress was applied to the site, the vascularity of the entire area increased. That, in turn, enhanced the ability of the ends to unite [11]. Distraction osteogenesis could achieve union, correct deformity, eradicate disease, reestablish length, and eliminate defects while at the same time maintaining articular function and allowing weight bearing as tolerated [11]. Grafting might be needed at the docking site to shorten the duration of healing and prevent non-union [12].
This study included 44 cases of tibial defects that had been treated by distraction osteogenesis using the external fixator. All s united, union time ranged from 6 months to 24 months, with an average of 15 months. In this series, 25 cases (56.8%) were male, and 19 cases were female (43.2%). This was explained by the fact that males were more prone to injury than females, and this finding was consistent with Hosny et al. [12]. The right side was affected in 22 cases and the left side in 22 cases; these findings are in accordance with Dendrinos et al. [7].
In this study, open fracture cases were 30 and closed fracture cases were 7. In agreement with Dendrinos et al**.** [7], who stated that 21 cases developed nonunion after open fracture and 7 cases after closed fracture. The average length of the defects was 6.1 cm. At an average follow-up of 15 months. In this series, 30 cases (68.2%) were free of disease at the final follow-up; 10 cases showed persistent minimal drainage and responded to antibiotics after culture, sensitivity testing; and 4 cases showed unchanged disease that needed further technique interference by the local. The results in this series compared favorably with those of others. Paley et al. [13] reported a success rate of 77%. Toh and Jupiter [14], who treated 39 cases with lengthening grafts, had only a 61% success rate. On the other hand, Dendrinos et al. [7] recorded eradication of disease with achievement of union in all their cases except for one with a success rate of 96.4%. Our success in eradicating disease and at the same time achieving union had been believed because the basic technique principles for treating disease had been applied by excision of all unhealthy tissues; this had been achieved by local but most required excision of a segment of which regrows from regions of good vascularity, avoiding the use of grafts.
The union had achieved this without the need for graft in 30 cases, with graft in 14 cases. The time ranged from 6 months to 24 months, with an average of 15 months. The duration of frame application had a disadvantage, but when all other modalities had failed, this technique was probably the only alternative and the only hope for many suffering cases, though the case's compliance was important for a successful outcome. The average number of operations per case was 3 (range from 1 to 5). The results of the present study agreed with other series involving the same technique. Dendrinos et al. [7] treated twenty-eight cases aged 18–74 years old with distraction osteogenesis for diseased non-union of the tibia. He reported satisfactory results in 78.8% of the cases and satisfactory functional results in 64.3% of the cases. The defects in this study ranged from 4 cm to 15 cm, with an average of 8.5 cm. The time in the present study ranged from 6 months to 24 months, with a mean of 15 months. The external time in the present study agreed with other series involving the same technique. The external time in the series of Paley and Maar [15] ranged from 6 to 22 months, with a mean of 16 months.
All the necrotic, diseased tissue had to be removed to get better control of the disease. This policy of radical agreed with Polyzois et al. [16], who stated that radical was important to eradicate the disease completely. The incidence of unsatisfactory results in the diseased cases (13.6%) was higher than that in the non-diseased cases (12.5%). However, this relationship was found statistically to be insignificant. One of the most important advantages of this method was its ability to bridge soft tissue defects without the need for major plastic surgery [16]. The benefits of treating non-unions with transport include the ability to achieve regeneration by living with the same strength and width as native bone [17]. Out of 37 (75%) in the study of Toh and Jupiter [14], soft tissue reconstruction had been performed. The method could achieve union at the pseudoarthrotic site, correct the deformities, and maintain the length. The technique has been

useful in many cases of congenital pseudoarthrosis (C.P.T.) in which union failed to occur despite many previous surgeries. The use of this method does not preclude the use of other procedures. The method takes considerable time and effort to obtain good results. The surgeon must know when to abandon this procedure, perform an amputation, which would make the case more functional [18].

In this study, there were four cases of congenital pseudoarthrosis. Despite the refractory nature of the disease, union had been achieved with the initial in three of them. This result (75%) was better in comparison to the results of the previously mentioned modalities for this trouble [19, 20]. All the cases united with the initial management; the disease had been eradicated in all the diseased cases. Thus, distraction histogenesis had a critical role in this trouble. In a study performed by Tranquilli et al. [20] in Italy on 20 cases with non-union of the tibia, the result was union in all the cases, with the mean time of union being 4.5 months. In another study, Marsh et al. [21] showed union in 40 out of 46 non-union cases treated with the method, with a high level of cases. Menon et al. [22] also concluded in their study that there was a role for ring with nail retention in resistant long diaphyseal non-union and that this method could achieve high union rates where other methods failed. Several modifications had been undergone to increase the efficacy of the method and the case's acceptability, e.g., Rozbruch et al. [23] used a computer-programmable spatial frame in two cases of hypertrophic non-union of the tibia with deformity for which distraction had been utilized, yielding noticeable results.

Union was achieved by repairing defects with grafts, as recommended by Johnson et al. [24] and Lack et al. [25], which might be satisfactory, but the biomechanical structure of the restored tissue might require years of remodeling to achieve the radiological appearance that had been obtained by distraction regeneration by the method [26]. Cattaneo et al. [27] reported that 5 of 28 cases had mild intermittent drainage after achieving union, and that disease resolved without antibiotic therapy in 23 of 28 cases. Chronic osteomyelitis had a unique pathology in that both biological and mechanical factors were affected. In this series, there were 10 cases of chronic osteomyelitis treated by radical resection of the diseased bone, transport from a healthy region. The disease had been completely eradicated; the results were satisfactory in 8 cases and unsatisfactory in 2 cases. Barbarossa et al. [28] described 30 cases of chronic post-traumatic osteomyelitis with diseased nonunion and defects of the femur, none of whom underwent grafts at the docking site; no nonunion occurred.

In this study, the distal third had the highest site of nonunion. This may be explained by being more exposed to trauma. This agreed with Toh and Jupiter [14], who stated that the most severe injury occurred in the distal third of the tibia. The nonunion at the docking site was a complicated factor in transport. In some cases, grafting was recommended at the time of docking to prevent the complications of nonunion; however, there was no evidence that grafting was necessary at the docking site. Cattaneo et al. [26] reported that circular external use of the apparatus combined with internal transport or compression-distraction techniques had been used to treat 28 cases with diseased non-unions or segmental loss of the tibia. In all cases, their diseased extremities healed without the addition of grafting, microvascular fibular grafting, or soft tissue grafting. Dendrinos et al. [7] treated defects of the tibia in 28 cases using the transport method of compression at the docking site for union. Grafts were required in only three cases. External fixation had also been associated with several complications, although most of these were minor. Pin tract diseases form the bulk of the complications associated with external fixation. Although the disease was superficial and mild in most of the cases, it increased the risk of wire loosening and due to the weight borne by the external frame, caused frame instability [29–32]. Good care of pin sites and aggressive management of superficial diseases are essential to preventing deep diseases, such as septic arthritis (associated with wires placed less than 1 cm from the subchondral bone). Insufficient pin care has been associated with a higher incidence of pin tract complications [29–32].

The delayed union of the docking site was one of the complications encountered with transport. In this study, delayed union of the docking site occurred in 14 of the 44 cases that needed to be grafted to complete union. Green et al. [33] found it necessary to do grafting in six of their 14 cases. Song et al. [34] recommended grafting of the docking site to reduce the duration of healing. Thus, graft was more required for healing in the older age group than in the younger age group. In large-segment transport, the forward end of the transported segment becomes covered with a layer of fibrous tissue and non-viable bone.

To prevent malalignment, soft tissue interposition, followed by enhancement of the union, was done over a wire placed in the intramedullary canal. In this study, 5 cases out of 44 had intramedullary nailing done. **Paley et al. [35]** reported interposed soft tissue hindering transport in two cases of severe (16, 17 cm) defects. To prevent malalignment, soft tissue interposition and transport were done over a wire placed in the intramedullary canal in four cases. The wire allowed the transport fragment to maintain its proper course to prevent the interposition of soft tissue with subsequent skin invagination. **Cierny et al. [36]** compared the results of treating segmental tibial defects using transport and massive autologous grafts, and the results were in favor of the method. Furthermore, if the cases had a length discrepancy, they might not be corrected with conventional grafting but with transport. The results compared favorably with those of others.

CONCLUSIONS

Distraction histogenesis had a good solution for segmental tibial defects. The technique is complicated and requires a great deal of expertise to perform it successfully. Defect reconstruction was less expensive and easier to perform. Stable had a very important point during distraction osteogenesis. Graft at the docking site might be needed to enhance the union and shorten the time in cases where selection is very important. Soft tissue defects might close during transport without the need for major plastic surgery. The complications were numerous, but they could be reduced with the improvement of the experience. It was important to include the foot in the frame in large distal to proximal transport (more than 5 cm) to avoid equinus deformity. The major disadvantage of this procedure was its lengthy duration. Although laborious, when successful, the method was of dramatic benefit to the case. Weight bearing and functional body use are required for regeneration and healing. An analysis of follow-up X-rays should detect any angular deformities; all efforts must be made to correct them properly. Pin tract disease should be managed early to avoid disease. Physiotherapy was essential to prevent the occurrence or recurrence of joint contractures.

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