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Original Article

Management of Segmental Tibial Defect with Intercalary Bone Transport by Ilizarov Method

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ABSTRACT

Objective: To determine the outcomes of intercalary bone transport using the Ilizarov technique in patients with segmental tibial defects.

Methodology: This empirical investigation was conducted at Shaheed Mohtarma Benazir Bhutto Medical University (SMBBMU), Larkana, during January 2023 to December 2024 to evaluate the consequences of intercalary bone transport in individuals aged between 18 and 65 years across both genders, ASA class I to III. The results were appraised utilizing the ASAMI criteria at intervals of 1, 3, and 6 months postoperatively. Data was analyzed by employing SPSS version 26, with outcomes categorized as excellent, good, fair, or poor.

Results: A total of fifty patients (mean age 33.7 ± 12.5 years; 80% male) underwent treatment utilizing intercalary bone transport. The incidence of pin tract infections was recorded at 74%, nonunion 32%, limb length discrepancies 42%, and infections 38%. Radiological results were categorized as excellent in 56% of cases, good 36%, and poor 8%. The functional outcomes were markedly influenced by the occurrence of complications, with bone grafting required in 32% of instances and refracture manifesting in 12% of cases.

Conclusion: The Ilizarov intercalary bone transport technique is a dependable and efficacious intervention for addressing segmental tibial defects, resulting in favorable radiological and functional outcomes. The occurrence of pin tract infections, discrepancies in limb length, and nonunion was prevalent; however, these complications did not markedly hinder the success of the treatment. Precision in surgery, patient compliance, and thorough postoperative care reduce complications and improve outcomes.

Keywords: Bone regeneration, Ilizarov technique, Intercalary bone transport, Orthopaedic outcomes, Segmental tibial defects

INTRODUCTION

Segmental osseous defects of the tibia constitute one of the most complex and high-risk challenges faced in the realms of orthopedic trauma and reconstructive surgery, having an overall yearly incidence of 51.7 per 100,000 often requiring prolonged treatment periods[1]. Such defects commonly arise as a result of high-energy trauma, infectious processes, tumor excisions, or the failure of previous surgical interventions; if left unaddressed, they may precipitate considerable functional impairments and increased morbidity[1,2]. The principal aims of management include the re-establishment of length, alignment, stability, and functionality of the limb, while concurrently minimizing the risk of complications such as infections, non-union, and joint stiffness.

Numerous methodologies for the reconstruction of critical-sized tibial bone defects have been documented, including bone grafting, the induced membrane (Masquelet) technique, vascularized fibular grafts, and distraction osteogenesis[3,4]. Among these, apoptosis induction through circular external fixation utilizing the Ilizarov technique, grounded in distraction osteogenesis, remains one of the most efficacious and adaptable strategies for the reconstruction of extensive segmental defects, particularly within the tibia[5]. In essence, deformity correction, bone lengthening, and defect reconstruction can be executed concurrently, and the defect site does not necessitate internal implants, especially when these cases are further complicated by infections[6].

The utilization of the Ilizarov apparatus for intercalary bone transport has been substantiated as an effective methodology for the correction of such defects by facilitating the generation of new bone during the process of distraction osteogenesis[6,7]. The minimally invasive characteristics of this technique not only promote the regeneration of bone but also improve the healing mechanisms of the adjacent soft tissues. Depending on the size of the defect and the status of the affected extremity, bone transport may be performed unifocally or bifocally. Nevertheless, the methodological framework is not devoid of limitations, which encompass the extended duration of external fixation application, the incidence of pin tract infections, the manifestation of joint stiffness, non-union at the docking site, in addition to difficulties associated with patient adherence[8,9]. A comprehensive investigation documented favorable radiological results in 87.5% of individuals managed with the Ilizarov external fixator, wherein 54.2% attained excellent outcomes and 33.3% yielded good results, while a mere 12.5% exhibited suboptimal outcomes[10].

Research investigations have meticulously examined alterations to the traditional bone transport technique by amalgamating it with intramedullary nails or locking plates to bolster structural integrity and minimize the duration of external fixation[7,10]. These composite strategies have particularly exhibited effectiveness in reducing complication rates and enhancing patient comfort. Moreover, advancements in surgical techniques, preoperative assessments, and postoperative rehabilitation frameworks have significantly facilitated the enhancement of clinical outcomes[11,12].

Empirical evidence acquired from a multitude of medical institutions substantiates the efficacy of the Ilizarov technique. For instance, Kukreja et al. documented positive results in

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individuals exhibiting tibial bone deficiencies surpassing 11 cm, signifying that this approach is effective even for significant deficiencies[8]. In a similar vein, Ghorab et al. implemented segmental bone transport in a significant sample of patients and recorded elevated union rates in conjunction with favorable complication profiles[11]. Moreover, Abosalem et al. substantiated the relevance of this methodological approach within the context of Egyptian populations, while simultaneously illustrating its versatility across diverse healthcare frameworks[12].

Notwithstanding the necessity for a considerable level of proficiency from the surgeon and a high degree of adherence from the patient, the unique benefit of biological bone regeneration, devoid of donor site morbidity, remains a critical factor to consider[13]. The methodological frameworks delineated by McNally et al. regarding the Ilizarov technique, which is meticulously applied in the treatment of infected non-unions, serve to further validate this principle and affirm its relevance in more complex clinical contexts[14]. Moreover, the empirical studies conducted by Alshahrani et al. yield significant insights related to the clinical understanding associated with its application in severe tibial deficiencies[15]. The primary aim of the present investigation is to evaluate the clinical outcomes of patients who have received intervention through the Ilizarov intercalary bone transport technique for the reconstruction of segmental tibial defects, with the intent of enhancing the existing corpus of scholarly literature and clarifying the factors associated with treatment results, incidence of complications, and functional outcomes.

METHODOLOGY

This empirical investigation was conducted within the Department of Orthopaedics at Shaheed Mohtarma Benazir Bhutto Medical University (SMBBMU) located in Larkana, spanning the period from January 2023 to December 2024, employing a non-probability, consecutive sampling approach to include the sample of 50 patients. The sample size was calculated based on an expected satisfactory radiological outcome of (87.5%)[9], with a margin of error (d) 9.2% and a 95% confidence level.

Individuals aged between 18 and 65 years, regardless of gender, who presented with segmental tibial defects—defined radiologically as the presence of at least two fracture lines that isolate a segment of the long bone—and who possessed an ASA classification of I–III were included subsequent to obtaining informed written consent. Individual's history of osseous abnormalities, pathological bone fractures, compound fractures, or multiple traumatic injuries were excluded from the research study. At the time of enrollment, demographic and clinical characteristics were meticulously recorded utilizing a pre-designed proforma.

All surgical interventions were conducted under either spinal or general anesthesia and comprised three distinct phases of bone transport utilizing external fixation, subsequently succeeded by the application of locking plates. In the initial phase, continuous debridement (with an average of 2.5 sessions) was executed until the infection was effectively managed. Necrotic bone was excised until hemostasis was achieved at both the proximal and distal margins of the defect, with the harvested specimens dispatched for microbiological culture. Temporary stabilization was accomplished through the application of double nails and antibiotic-laden bone cement containing 3 g of vancomycin. Soft tissue closure was executed, and the management of infection was diligently observed through the systematic assessment of erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), and procalcitonin levels during the initial month. In the following stage, reconstructive efforts commenced subsequent to the confirmation of the absence of any clinical or laboratory signs indicative of infection. The external fixator and bone cement were removed, and internal fixation utilizing locking plates was instituted. A corticotomy was performed at the metaphyseal region, and distraction osteogenesis commenced on the tenth postoperative day at a rate of 1 mm per day (0.25 mm, administered four times daily).

Patients were prompted to engage in joint mobilization exercises commencing on the first postoperative day and underwent biweekly radiographic evaluations to monitor callus development. The administration of antibiotic therapy was sustained for a duration of 2 to 4 weeks, contingent upon the results of microbial cultures and serological assessments. Union was operationally defined as the presence of bridging trabecular structures across three cortices, the absence of pain during dynamization, and the lack of movement at the union site as visualized on fluoroscopy. In the concluding phase of treatment, following the alignment and pressurization of the transport segment, the insertion of the cortical bone screw was executed in accordance with the principles of compression screw mechanics, subsequent to which the external fixator was removed. Patients were directed to progressively augment their weight-bearing exercises and were subjected to systematic clinical evaluations and radiographic examinations on a monthly basis. Full loading was permitted upon the successful development of three cortical layers within the transport segment. Outcome metrics were assessed at intervals of 1, 3, and 6 months postoperatively, utilizing the ASAMI criteria to evaluate both bone and functional recovery[16]. Bone outcomes were classified as Excellent, Good, Fair, or Poor, based on the degree of infection eradication, bone union, limb length discrepancy (LLD), and deformity correction. An Excellent bone outcome was defined as complete infection clearance, solid bone union, deformities less than 7°, and LLD under 2.5 cm. Good outcomes required bone union plus any two of the following: infection clearance, deformities less than 7°, or LLD under 2.5 cm. Fair outcomes included bone union with persistent infection, deformities under 7°, and LLD greater than 2.5 cm, while Poor outcomes indicated nonunion, active infection, severe deformities over 7°, and LLD greater than 2.5 cm. Functional outcomes were assessed separately to capture the clinical recovery of the patient. These were similarly categorized as Excellent, Good, Fair, or Poor, based on mobility, joint stiffness, reflex sympathetic dystrophy (RSD), and pain levels. Excellent function was defined as active patients without limp, minimal knee stiffness (<15° loss of extension), no RSD, and no significant pain. Good function included active, pain-significant individuals without limp, no RSD, and up to 20° loss of knee extension. Fair function indicated active but limping patients with knee stiffness, RSD, and significant pain, while Poor function represented inactive individuals unable to return to daily activities. In addition to these criteria, radiographic evaluation was conducted to confirm bone healing, assess alignment, and identify potential complications, ensuring a comprehensive assessment of both structural and functional recovery. An overall outcome was considered satisfactory if Excellent results were achieved in both the bone and functional domains.

All data were diligently recorded in a prestructured proforma. Data analysis was performed using SPSS version 26. Descriptive statistical methods were employed to present the

mean alongside the standard deviation for quantitative variables, whereas frequency distributions accompanied by percentages were computed for qualitative variables. The Chi-square test was utilized to evaluate the statistical significance at a 5% level of significance.

RESULTS

The investigation encompassed a cohort comprising 50 individuals, with a mean age of 33.72 ± 12.53 years and an average treatment duration of 10.06 ± 3.29 weeks. A notable proportion of the subjects were male (80%), and a substantial percentage of the debridement lesions were observed in the distal third of the tibia (54%), followed by the proximal third (26%) and the middle third (20%) of the tibia, respectively. In terms of smoking habits, 44% were identified as smokers, while 56% were categorized as non-smokers. Road traffic accidents were identified as the principal etiology, succeeded by congenital pseudoarthrosis, firearm-related injuries, and injuries from rock fragments (42%, 32%, 18%, and 8%, respectively). With respect to the fractures, 74% were categorized as open fractures, whereas 26% were classified as closed fractures; moreover, 38% of the participants demonstrated signs of infection. Prior to the debridement intervention, 64% of the subjects presented with a defect measuring ≤ 6 cm, while 36% displayed a defect length exceeding 6 cm. A total of 66% of the cases underwent proximal corticectomy, whereas 34% underwent distal corticectomy **(Table I)**.

A total of fifty subjects engaged in the tibial segment bone transport procedure, as delineated in **Table II**, alongside the concomitant complications that were observed. The most prevalent complication identified was pin tract infection, which occurred in 74% of the studied population, while 26% of the participants did not exhibit this pathology. Among those afflicted, 12% subsequently sustained a refracture, in contrast to 88% who did not. Furthermore, 38% of the participants developed an infection. In 42% of the instances, limb length discrepancies were noted, while 58% exhibited no such discrepancies. A nonunion was observed in 32% of the participants, whereas 68% achieved successful union. A malunion was documented in 10% of the cases, suggesting that 90% of the patients did not encounter this particular complication. Furthermore, merely 6% of the patients exhibited signs of compartment syndrome. Among the diverse complications, foot equinus was observed in 8% of the subjects, whereas impingement was the least frequently reported, manifesting in only 4%. In addition, the requirement for bone grafting was recognized in 32% of the subjects.

In terms of radiological outcomes, 56% as excellent, 36% as good and 8% as poor as shown in **Figure I**.

In the assessment of functional outcomes influenced by postoperative complications, pin tract disease emerged as the predominant complication, manifesting in 76.7% of individuals who attained excellent results, 66.7% within the cohort displaying good and fair results, and a comprehensive prevalence of 100% within the subgroup classified as having poor outcomes (p=0.725). The incidence of refracture was documented in 10.0% of individuals exhibiting exemplary results and in 25.0% of those attaining satisfactory outcomes, whereas no instances were detected within the classifications categorized as fair or poor outcomes (p=0.373). The occurrence of infection was observed in 30.0% of patients achieving excellent results, 41.7% among those with satisfactory outcomes, 66.7% in the fair outcome classification, and 50.0% in the group identified as having poor outcomes (p=0.377). Limb length discrepancy (LLD) was identified in 46.7% of individuals exhibiting excellent outcomes, 33.3% of those displaying good outcomes, 16.7% within the fair outcome classification, and a complete prevalence of 100% in the cohort characterized by poor outcomes (p=0.173). The phenomenon of nonunion was detected in 30.0% of patients achieving excellent outcomes, 41.7% in those classified as having good outcomes, and 33.3% within the fair outcome classification, whereas no instances were documented in the cohort with poor outcomes (p=0.678).

Malunion was noted in 16.7% of patients demonstrating outstanding clinical results, with no occurrences recorded within the alternative outcome classifications (p=0.295). The prevalence of compartment syndrome (CS) was rare, manifesting in 6.7% of individuals with excellent outcomes and 8.3% of those with good outcomes (p=0.885). The presence of foot equinus deformity was identified in 6.7% of patients demonstrating excellent outcomes, 8.3% of those with good outcomes, and 16.7% among patients with fair outcomes (p=0.835). Impingement phenomena were documented in 6.7% of the cohort with excellent outcomes, while absent in the remaining groups (p=0.708). Ultimately, the requirement for bone grafting was determined in 33.3% of patients with excellent outcomes, in 16.7% of those with good outcomes, and in 50.0% of patients categorized with fair and poor outcomes (p=0.473), as illustrated in **Table III**.

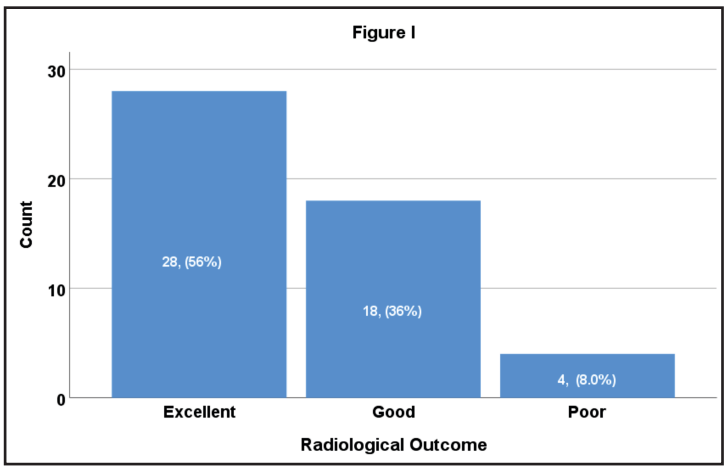

Table I: Demographic and Clinical Characteristics of Study Participants (n=50)			
Age in years (Mean ± SD) = 33.72 ± 12.53		**Frequency**	**Percent**
Duration of Treatment in months (Mean ± SD) = 10.06 ± 3.29			
Gender	Male	40	80.0
	Female	10	20.0
Level of the Defect After Debridement	Lower Third	27	54.0
	Middle Third	10	20.0
	Upper Third	13	26.0
Smoking Status	Smoker	22	44.0
	Non-Smoker	28	56.0
Etiology	Road traffic accident	21	42.0
	Congenital Pseudoarthrosis	16	32.0
	Firearm Injury	9	18.0
	Injury Due to Falling Rock Piece	4	8.0
Type of Fracture	Open	37	74.0
	Closed	13	26.0
Length of the Defect After Debridement	≤ 6 cm	32	64.0
	> 6 cm	17	36.0
Corticectomy Site	Proximal	33	66.0
	Distal	17	34.0

Table II: Postoperative Complications Following Tibial Segment Bone Transport Using the Ilizarov Technique (n=50)			
Type of Complication		**Frequency**	**Percent**
Pin Tract Disease	Yes	37	74.0
	No	13	26.0
Refracture	Yes	6	12.0
	No	44	88.0
Infection	Yes	19	38.0
	No	31	62.0
Limb Length Discrepancy	Yes	21	42.0
	No	29	58.0
Nonunion	Yes	16	32.0
	No	34	68.0
Malunion	Yes	5	10.0
	No	45	90.0
Compartment Syndrome	Yes	3	6.0
	No	47	94.0
Foot Equines	Yes	4	8.0
	No	46	92.0
Impingement	Yes	2	4.0
	No	48	96.0
Need for Bone Grafting	Yes	16	32.0
	No	34	68.0

Table III: Postoperative Complications & Functunal Outcomes (ASAMI) in Ilizarow Transport (n=50)					
Type of Complication, n (%)	Functional Outcomes				P-Value
	Excellent	Good	Fair	Poor	
Pin Tract Disease	23 (76.7%)	8 (66.7%)	4 (66.7%)	2 (100.0%)	0.725
Refracture	3 (10.0%)	3 (25.0%)	0 (0.0%)	0 (0.0%)	0.373
Infection	9 (30.0%)	5 (41.7%)	4 (66.7%)	1 (50.0%)	0.377
Limb Length Discrepancy	14 (46.7%)	4 (33.3%)	1 (16.7%)	2 (100.0%)	0.173
Nonunion	9 (30.0%)	5 (41.7%)	2 (33.3%)	0 (0.0%)	0.678
Malunion	5 (16.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0.295
Compartment Syndrome	2 (6.7%)	1 (8.3%)	0 (0.0%)	0 (0.0%)	0.885
Foot Equines	2 (6.7%)	1 (8.3%)	1 (16.7%)	0 (0.0%)	0.835
Impingement	2 (6.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0.708
Need for Bone Grafting	10 (33.3%)	2 (16.7%)	3 (50.0%)	1 (50.0%)	0.473

DISCUSSION

The existence of a segmental defect in the tibia presents a formidable challenge in the field of orthopedic surgery, usually arising from various etiological factors including trauma, infection, or the excision of tumors. The utilization of intercalary bone transport through the Ilizarov technique has become a prominent and frequently adopted approach for resolving these complex clinical issues. The objective of our investigation was to evaluate the outcomes and complications associated with this technique and to juxtapose our findings with the extant literature to furnish a more thorough context for our results.

The complication profile delineated in our investigation aligns with the established complications consistently documented in association with the Ilizarov technique. The incidence of infection at the pin tract was identified as the predominant complication, impacting 74% of our subjects, which bears resemblance to the results articulated by Gohrab et al. at 77.7%[11].

This heightened occurrence underscores the critical need for diligent care at the pin sites and the significance of thorough patient education throughout the entirety of the treatment process. Infection emerged as another significant complication within our group (38%), which, although concerning, reflects the inherent risks associated with the management of extensive bone defects, particularly in scenarios characterized by antecedent infections or open fractures.

Limb length discrepancy was documented in 42% of our subjects, which is marginally lower than the 45% indicated by Gohrab et al[11]. Such discrepancies may arise from uneven regenerative formation or premature consolidation, underscoring the necessity for meticulous surveillance during the distraction phase. Refracture was documented in 12% of our cohort, which is consistent with the 13.6% incidence reported in the study conducted by Gohrab, thereby underscoring the critical necessity for extended protective measures subsequent to the removal of the fixator to mitigate this event[11].

Nonunion and malunion were noted in 32% and 10% of the cases examined in the current study, respectively. These results align with those documented by Gohrab et al., who reported nonunion in 31.8% and malunion in 9.1% of their examined cohort[11]. The previously mentioned complications can be attributed to inadequate vascular supply, substandard quality of the regenerate, or mechanical instability, and often require additional interventions, including bone grafting, which was indicated in 32% of our cases. Additional complications, such as compartment syndrome (6%), foot equinus (8%), and impingement (4%), exhibited a frequency comparable to that observed by Gohrab et al., who recorded 4.5% for each of these complications[11]. These less prevalent yet potentially grave complications highlight the necessity for thorough postoperative surveillance and a multidisciplinary approach to management.

The radiological results identified in our study were classified as excellent (56%), good (36%), and poor (8%) within the patient population. These findings exhibit a remarkable degree of congruence with extant literature, including a comparative analysis that delineated excellent (54.2%), good (33.3%), and poor (12.5%) radiographic outcomes[12]. Similarly, our functional outcomes—categorized as excellent (60%), good (24%), fair (12%), and poor (4%)—exhibited a notable congruence with the findings from the comparative study, which documented excellent (58.3%), good (25%), fair (12.5%), and poor (4.2%) functional metrics[12]. Such parallels underscore the efficacy of the Ilizarov technique in achieving favorable outcomes, notwithstanding its rigorous demands and associated complications.

Further supporting our findings, a meta-analysis by Ren et al. compared the Ilizarov method with the Masquelet technique and highlighted the former's superior results in limb length restoration and infection control, albeit with a higher rate of complications[17]. Similarly, Liu et al. reviewed 282 cases over ten years and reported a broad range of complications, emphasizing the importance of surgeon experience and patient compliance[18].

Lastly, Tetsworth et al. contributed to a better understanding of bone defect classification, which aids in the surgical planning and prognosis of such challenging cases[19]. Incorporating such classifications can refine treatment protocols and anticipate complications more effectively.

The absence of statistically significant associations (P>0.05) between complications and functional outcomes is acceptable given our small sample size (n=50) and the low frequency of individual complications. These factors limit statistical power and increase the risk of type II error. However, clinically important complications like infection, limb length discrepancy, and nonunion still warrant close attention, as they can significantly affect long-term outcomes—especially in resource-limited settings. Thus, while not statistically significant, their clinical relevance remains high. The intercalary bone transport using the Ilizarov method remains a valuable and effective option for managing segmental tibial defects. Despite a notable rate of complications, the technique yields encouraging radiological and functional outcomes. Careful patient selection, meticulous surgical technique, and close follow-up are essential to minimize complications and optimize results.

A primary limitation of this study is the comparatively constrained sample size (n=50), which may restrict the generalizability of the results to wider populations. Furthermore, the employment of non-probability consecutive sampling introduces the potential for selection bias, which may curtail the representativeness of the study cohort. Furthermore, the metrics pertaining to the duration of follow-up and patient compliance were insufficiently delineated, which could potentially undermine the reliability of assessments regarding long-term functional outcomes.

Despite the constraints outlined in the preceding analysis, this study offers a comprehensive assessment of both radiological and functional outcomes, juxtaposing these findings with the established knowledge documented in the scholarly literature. The spectrum of complications documented facilitates an authentic representation of the genuine difficulties associated with the implementation of the Ilizarov method. The uniformity of outcome metrics promotes comparability with alternative investigations, thereby strengthening the credibility of the findings. Subsequent investigations ought to contemplate the implementation of more extensive, multicentric randomized controlled trials to evaluate the efficacy of the Ilizarov technique in relation to alternative reconstructive modalities. Longer follow-up periods and standardized outcome assessment tools are also recommended. Improved patient education and follow-up protocols may help reduce complication rates, particularly pin tract infections and limb length discrepancies.

CONCLUSION

The Ilizarov intercalary bone transport technique is a dependable and efficacious intervention for addressing segmental tibial defects, resulting in favorable radiological and functional outcomes. The occurrence of pin tract infections, discrepancies in limb length, and nonunions was prevalent; however, these complications did not markedly hinder the success of the treatment. Precision in surgery, patient compliance, and thorough postoperative care reduce complications and improve outcomes. This method remains relevant in complex or resource-limited clinical settings.

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