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Clinical Outcomes of Bone Transport Over Intramedullary Nail by Ilizarov Method

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Abstract **Original Research Article**

Background: The Ilizarov method for bone transport over intramedullary nail represents a significant advancement in orthopedic surgery, particularly for managing complex long bone defects due to trauma, infection, or gap non-union. ***Aim of the study:*** The aim of this study was to assess the clinical outcomes of bone transport over intramedullary nail by Ilizarov method. ***Methods:*** This retrospective observational study was conducted in Ilizarov & Deformity Correction Unit, National Institute of Traumatology & Orthopaedic Rehabilitation (NITOR) and Private Hospital, Dhaka, Bangladesh, during the period from January 2019 to December 2024. ***Result:*** The study subjects had a mean age of 35.4 years (SD± 12.6 years), with a male: female ratio of 2.2:1. The mean defect size was 5.4 ± 1.8 cm, mostly affecting the femur (56.25%). Rush Nail was used in 31.25% of cases, Kuntscher Nail in 25%, interlocking nails in 18.75%, and Proximal Femoral and SIGN Nails in 12.5% cases. Union rate was 100%, with complications including insomnia (56.25%) pin track infections (37.50%) and joint stiffness (31.25%). Pain levels peaked on the first day post-operation, with a mean score of 7.8 ± 1.2. It reached 2.5 ± 0.9 by the seventh day ($p < 0.001$). ASAMI scores showed 92.75% excellent bone outcomes and 62.50% excellent functional outcomes. ***Conclusion:*** This study demonstrates the effectiveness of bone transport over intramedullary nails using the Ilizarov method in managing long-bone defects.

Keywords: Clinical Outcomes, Bone Transport, Intramedullary Nail, and Ilizarov Method.

INTRODUCTION

Bone defects and nonunion fractures represent significant clinical challenges globally, particularly in regions with high trauma prevalence and limited healthcare resources. These defects are often caused by trauma or infections, resulting in severe functional impairments and reduced quality of life if untreated [1]. Among these, trauma is the leading cause worldwide, with road traffic accidents accounting for the majority of cases. In Bangladesh, 5,084 road traffic accidents occurred only in 2021 [2]. According to the US FDA definition, a fracture ununited 9 months after injury or one in which there is a failure of progression towards union over the previous three months, can be classified as a nonunion [3]. Addressing these issues in resource-constrained settings requires cost-effective and effective solutions. The Ilizarov method, developed by Dr. Gavriil Abramovich Ilizarov, has revolutionized the treatment of complex bone defects. This method, grounded in the principles of distraction osteogenesis, utilizes gradual mechanical tension to stimulate new bone formation across an corticotomy site [4]. The approach not only addresses large segmental defects but also facilitates the correction of angular deformities, making it particularly suitable for lower-limb reconstruction [5]. Despite its efficacy, the extended duration of external fixation required by traditional Ilizarov techniques often leads to significant patient discomfort, increased risk of pin-site infections, and psychological distress [6]. To mitigate

these limitations, hybrid approaches that integrate intramedullary nails with Ilizarov fixators have emerged as promising alternatives. Bone transport over intramedullary nails combines the mechanical stability of intramedullary devices with the biological advantages of distraction osteogenesis, effectively reducing external fixation duration and enhancing patient comfort [7]. This method maintains anatomical alignment and improves biomechanical stability, allowing for earlier mobilization and improved functional outcomes compared to traditional external fixators alone [8]. Studies show that bone transport over intramedullary nails can significantly shorten external fixation periods, with healing rates as high as 90%, while minimizing complications such as deformities and docking site nonunion [9]. However, the application of these techniques in resource-limited settings remains underexplored. In Bangladesh, where advanced surgical equipment and expertise are often lacking, implementing cost-effective and reproducible methods like the Ilizarov technique and its hybrid variations is crucial. Local studies underscore the potential of such interventions, with successful outcomes reported in 83.3% of aseptic nonunion cases treated using autogenous bone grafting combined with simpler surgical techniques [2]. Nonetheless, broader investigations into hybrid techniques are needed to determine their feasibility and scalability in low-income contexts. Existing literature also reveals substantial variability in outcomes and complications associated with bone transport over intramedullary nails. For instance, studies report external fixation durations ranging from 6 to 18 months, influenced by defect size, infection status, and surgical technique [7,10]. Complications, including pin-site infections (20-30%) and residual deformities, highlight the need for improved procedural standardization [6,8]. Furthermore, docking site nonunion rates remain a persistent issue, occurring in up to 15% of cases even with advanced techniques [9]. Despite these challenges, the potential benefits of hybrid methods in enhancing treatment adherence and reducing healthcare burdens are evident. By reducing the reliance on external fixation, bone transport over intramedullary nails minimizes patient discomfort and facilitates earlier return to daily activities [11]. Moreover, the technique's adaptability to various clinical contexts, including posttraumatic and postinfectious bone defects, underscores its relevance in addressing global and regional disparities in orthopedic care [12]. This study aims to evaluate the clinical outcomes of bone transport over intramedullary nails using the Ilizarov method in the Bangladeshi context.

Objectives

To assess the clinical outcomes of bone transport over intramedullary nail by Ilizarov method.

METHODOLOGY & MATERIALS

This retrospective observational study was conducted in Ilizarov & Deformity Correction Unit, National Institute of Traumatology & Orthopaedic Rehabilitation (NITOR) and Private Hospital, Dhaka, Bangladesh, during the period from January 2019 to December 2024. Total 16 patients aged between 12–65 years with post-operative non-union, aseptic non-union, post-operative infective non-union with nail in situ, osteomyelitis, and gap non-union were included in this study. Exclusion criteria included patients with congenital deformities, tumor or malignant condition or those who refuse to provide consent. All participants underwent preoperative assessment, including detailed medical histories, radiographic evaluations, and laboratory tests to ensure suitability for the procedure. The surgical procedure commenced with refreshing the fracture site, followed by debridement, nail application, Ilizarov frame construction, corticotomy, gradual distraction osteogenesis. Regular physical exercise was prescribed for each patient as part of the postoperative regimen. Pain management was effectively implemented from the immediate postoperative period until the removal of the fixator. Patients were closely monitored for proper alignment and the progression of callus formation through serial radiographic assessments, ensuring optimal outcomes during the treatment process. The external fixator was removed once radiological evidence of corticalization and union was observed, with an average external fixation duration expected to be 9-14 months. Ethical approval was obtained from the institutional review board, and written informed consent was obtained from all participants. After collection of data, all data were entered into computer and statistical analysis of the results being obtained by using windows-based computer software devised with Statistical Packages for Social Sciences version 22. P value of less than 0.05 was considered statistically significant.

Association for the Study and Application of Methods of Ilizarov (ASAMI) criteria for evaluating the bone and functional results:

Bone score	
Excellent	Union, no infection, deformity < 7° limb length discrepancy <2.5cm.
Good	Union + any two of the followings: No infection, deformity <7 ° limb length discrepancy < 2.5cm
Fair	Union + only one of the following: No infection, deformity <7° limb length discrepancy <2.5 cm.
Poor	Non-union /refracture /union + infection + deformity< 7 ° + limb length discrepancy >2.5 cm.

Functional score	
Excellent	Active, no limp, minimum stiffness (loss of < 15 ° knee extension/<15° dorsiflexion of ankle), no Reflex Sympathetic Dystrophy, Insignificant pain.
Good	Active with one or two of the followings: Limp, stiffness, R.S.D., insignificant pain.
Fair	Active with three or all of the followings: Limp, stiffness, R.S.D., significant pain.
Poor	Inactive (unemployment or inability to return to daily activities because of injury).
Failure	Amputation.

RESULT

The baseline characteristics of the study subjects (Table I) indicate that the mean age of participants was 35.4 ± 12.6 years, with a significant proportion being male (68.75%, p=0.036). The male: female ratio was 2.2:1. The mean defect size was 5.4 ± 1.8 cm, predominantly affecting the femur (56.25%) compared to tibia (43.75%) (p=0.042). Figure 1 outlines the distribution of intramedullary nail types used in the study population. The most frequently utilized nail was the Rush Nail, applied in 31.25% of cases, demonstrating its popularity for specific indications due to its simplicity and versatility. The Kuntscher Nail (K Nail) was used in 25% of patients, reflecting its continued relevance in managing long-bone fractures. The Conventional Intramedullary Interlocking Nail was employed in 18.75% of cases, highlighting its effectiveness in providing stability and alignment. Both the Proximal Femoral Nail and the SIGN Nail were used in 12.5% of patients each, indicating their specific use cases in managing fractures in different anatomical locations or clinical contexts. Clinical and surgical characteristics (Table II) showed that the mean docking time was 4.2 ± 0.7 months, with a range of 3.5 to 6.5 months. Consolidation time averaged 9.8 ± 1.3 months, ranging from 8.0 to 11.5 months. The external fixation time was slightly longer at 10.2 ± 1.5 months, with a range of 8.0 to 11.2 months. Finally, the external fixation index averaged 62.6 ± 8.4 days/cm, with a range of 55.0 to 75.0 days/cm. Table III summarizes the clinical outcomes and complications observed in the study subjects. The mean time to bone union was 12.8 ± 2.3 months, with an overall union rate of 87.5%, reflecting the effectiveness of the hybrid bone transport technique in achieving successful union in the majority of cases. However, complications were significant, with insomnia in 56.25%, pin track infections occurring in 37.50% of patients, and joint stiffness in 31.25%. Residual deformities were observed in 6.25% of cases, indicating a relatively low incidence of permanent structural abnormalities. These findings highlight the hybrid technique's high success rate but also emphasize the need to address complications associated with prolonged external fixation and bone transport. Table IV illustrates the progressive reduction in pain levels among the study patients as measured by the VAS score. Preoperatively, patients reported no pain (VAS = 0). Pain levels peaked on the first day post-operation, with a mean score of 7.8 ± 1.2, indicating the expected acute post-surgical pain. By the third day, pain had significantly reduced to 5.2 ± 1.1 ($p < 0.001$), reflecting the effectiveness of early pain management strategies. Pain levels continued to decrease, reaching 3.9 ± 1.0 by the fifth day and further reducing to 2.5 ± 0.9 by the seventh day (both $p < 0.001$). These findings illustrate a steady and statistically significant reduction in pain, demonstrating effective pain management and recovery progression during the first week after surgery. ASAMI scores (Table V) indicated favorable bone and functional outcomes. Excellent bone scores were achieved in 93.75% of patients, and 62.50% achieved excellent functional outcomes. Good bone and functional outcomes were reported in 6.25% and 31.25% of cases, respectively, while fair functional outcomes were seen in a small proportion (6.25%). There were no poor outcomes, underscoring the effectiveness of the method. Figure 2 to 5 shows the initial state of bone loss, surgical progress with intramedullary nail using Ilizarov method and final outcomes of some patients.

Table-I: Baseline characteristics of the study subjects (N=16)

Characteristics	**Frequency (n)**	**Percentage (%)**	**p-value**
Age (years)			
Mean ± SD	35.4 ± 12.6		-
Sex			
Male	11	68.75	0.036
Female	5	31.25	
Male: Female	2.2:1		
Defect Size (cm)			
Mean ± SD	5.4 ± 1.8		
Surgical area			
Femur	9	56.25	0.042
Tibia	7	43.75	

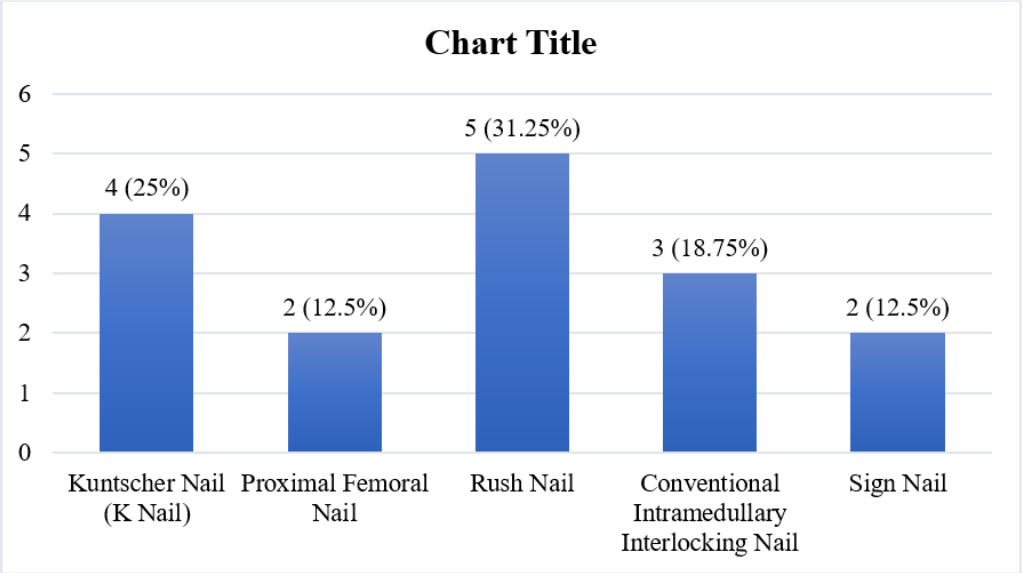

Figure 1: Types of nail used (N=16)

Table-II: Clinical and surgical characteristics of the study subjects (N=16)

Parameter	Mean ± SD	Range
Docking Time (months)	4.2 ± 0.7	3.5-6.5
Consolidation Time (months)	9.8 ± 1.3	8.0-11.5
External Fixation Time (months)	10.2 ± 1.5	8.0-11.2
External Fixation Index (days/cm)	62.6 ± 8.4	55.0-75.0

Table-III: Outcome measures of the study subjects (N=16)

Outcome	Frequency (n)	Percentage (%)
Time to union		
Mean ± SD	12.8±2.3	
Union rate (%)	100%	
Complications		
Insomnia	9	56.25
Pin track infection	6	37.50
Joint stiffness	5	31.25
Residual deformity	1	6.25

Table-IV: Visual Analogue Scale (VAS) score for pain assessment of the study patients (N=16)

Time Point	VAS Score (Mean ±SD)	P-value
Preoperative	0	-
At 1st day of operation	7.8 ± 1.2	<0.001
At 3rd day after operation	5.2 ± 1.1	<0.001
At 5th day after operation	3.9 ± 1.0	<0.001
At 7th day after operation	2.5 ± 0.9	<0.001

Table-V: ASAMI score of the study subjects (N=16)

ASAMI score	Bone score		Function score	
	n	%	n	%
Excellent	15	93.75	10	62.50
Good	1	6.25	5	31.25
Fair	0	0.00	1	6.25
Poor	0	0.00	0	0

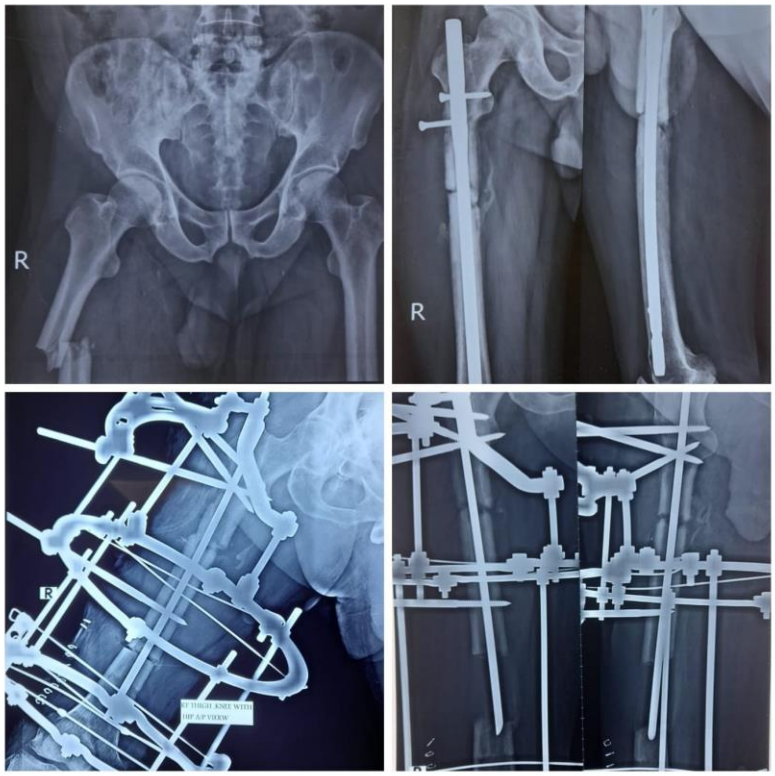

Figure 2: Radiographs of a 60 years old male patient showing femoral fracture before operation, after Rush nail application and Ilizarov frame construction

Figure 3: Radiographs of a 15 years old male patient showing femoral fracture before operation, after K-nail application with Ilizarov frame construction, and final outcome

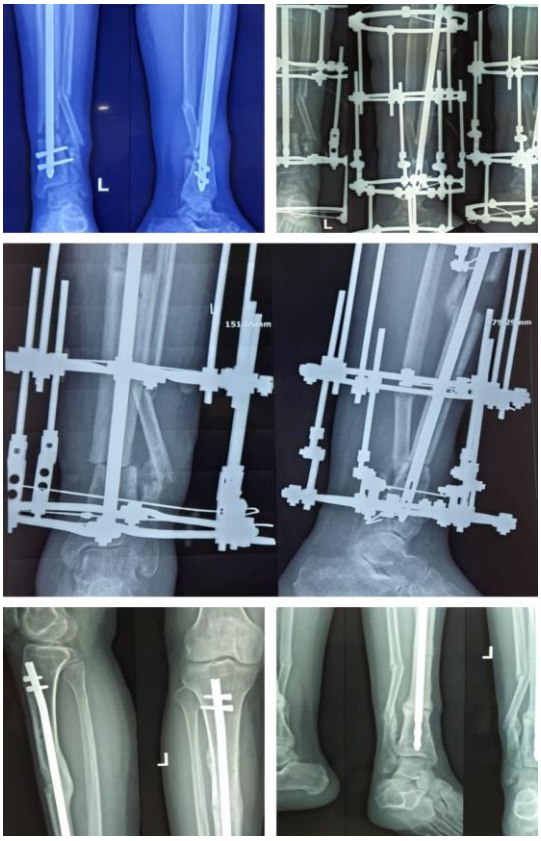

Figure 4: Radiographs of a 27 years old male patient with tibial fracture operated with SIGN Nail and application of Ilizarov frame

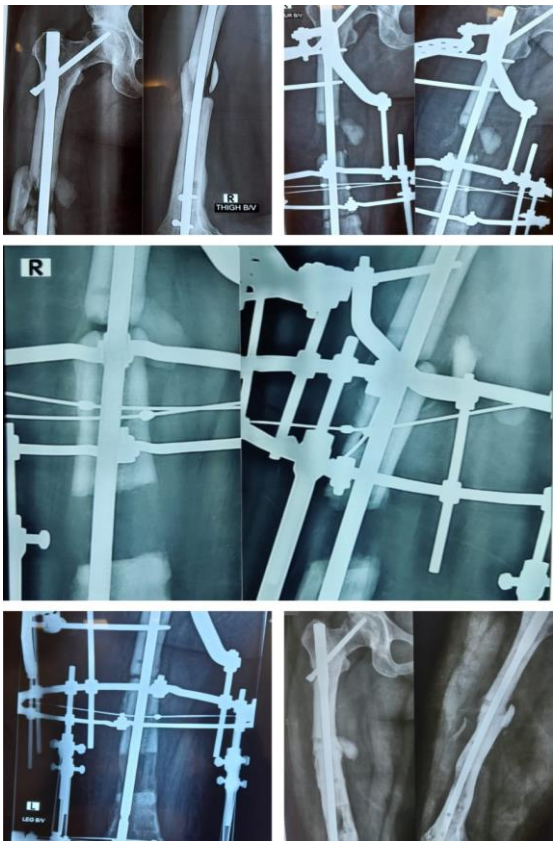

Figure 5: Radiographs of a 40 years old female patient showing femoral fracture before operation, after Proximal Femoral nail application and Ilizarov frame construction

DISCUSSION

This retrospective observational study was conducted in Ilizarov & Deformity Correction Unit, National Institute of Traumatology & Orthopaedic Rehabilitation (NITOR) and Private Hospital, Dhaka, Bangladesh, during the period from January 2019 to December 2024. A total of 16 patients with segmental bone defects resulting from trauma, infection, or nonunion fractures were included. The mean age of participants in this study was 35.4 ± 12.6 years, with 68.75% being male and 31.25% female. The male: female ratio was 2.2:1 These findings align with similar demographic profiles reported in other studies. For instance, Liu *et al.,* [13] documented a mean age of 40 years in a study of 282 patients undergoing bone transport using the Ilizarov method, with a comparable male predominance (86%). Similarly, Rosteius *et al.,* [14] reported a mean age of 45.5 years, with males representing a significant proportion of their cohort. The defect size in our study averaged 5.4 ± 1.8 cm. In this study, the femur was the most commonly treated site (56.25%), followed by tibia (43.75%). These results align with existing literature that emphasizes the femur and tibia as frequent targets for bone transport due to their vulnerability in high-energy injuries and nonunion. Studies by Zhang *et al.,* [15] (2018) and Liu *et al.,* [13] similarly reported a higher frequency of procedures in the femur and tibia, reflecting their critical load-bearing roles and susceptibility to complex fractures. Zhang *et al.,* [15] reported an average nonunion size of 10.9 ± 3.8 cm. The distribution of intramedullary nails in this study reflects a tailored approach to managing fractures. The frequent use of the Rush Nail (31.25%) highlights its enduring utility due to simplicity and adaptability. Previous studies have demonstrated the Rush Nail's effectiveness in addressing long-bone fractures with minimal complications [16]. Similarly, the Kuntscher Nail (25%) continues to play a role in fracture stabilization, particularly in resource-limited settings where advanced options may be unavailable [17]. Conventional intramedullary interlocking nails (18.75%) and Proximal Femoral Nails (12.5%) are recognized for providing enhanced mechanical stability, particularly in more complex fractures [18]. The SIGN Nail (12.5%) is a cost-effective alternative, often used in resource-constrained settings, with studies confirming its efficacy in achieving good outcomes in long-bone fracture management [19]. The mean docking time was 4.2 ± 0.7 months, with a range of 3.5 to 6.5 months, reflecting the time required for the transported bone segment to meet and integrate with the docking site. Consolidation time, representing the duration for complete bone healing and docking, averaged 9.8 ± 1.3 months, ranging from 8.0 to 11.5 months. The external fixation time, critical for maintaining stability during the transport and consolidation process, was slightly longer at 10.2 ± 1.5 months, with a range of 8.0 to 11.2 months. Finally, the external fixation index, calculated as the number of days of external fixation per centimeter of bone defect, averaged 62.6 ± 8.4 days/cm, with a range of 55.0 to 75.0 days/cm. These values are comparable to findings from studies using similar hybrid techniques. For instance, Liu *et al.,* [13] reported a mean docking time of 3.6 months and an external fixation index of 60-75 days/cm. In contrast, Zhang *et al.,* [15] noted an external fixation index of 1.1 ± 0.3 months/cm, suggesting that variations in methodology, defect size, and patient population can influence these metrics. The mean time to bone union of 12.8 ± 2.3 months and an overall union rate of 100% affirm the hybrid technique's effectiveness. Comparable outcomes have been reported in studies utilizing similar methods, with union rates ranging from 76% to 96% [20]. However, the high rates of complications, such as pin track infections (37.50%) and joint stiffness (31.25%), are consistent with the challenges noted in other studies. For example, Liu *et al.,* [13] reported pin track infection rates as high as 65.96%, emphasizing the inherent risks of prolonged external fixation. In our study, insomnia was observed in 56.25% of patients. Insomnia is a well-documented complication in postoperative care, often linked to pain, psychological stress, and the unfamiliar hospital environment [21]. Addressing insomnia requires a multidisciplinary approach, including optimized analgesia, environmental modifications, and psychological support. Pin track infection and joint stiffness, while significant, underscore the need for meticulous patient management and enhanced surgical techniques to reduce morbidity [22]. Residual deformity rates in our study are significantly lower than the 25% reported by Zhang *et al.,* [15], likely reflecting the biomechanical advantages of intramedullary nails in maintaining alignment. The challenges associated with infection and joint stiffness necessitate innovations in docking site management and adjunctive treatments such as bone grafting or biological enhancement [23]. Pain levels, as assessed using the Visual Analogue Scale (VAS), demonstrated a predictable perioperative trajectory. In this study, preoperative pain levels were reported as negligible, reflecting the stable condition before surgical intervention. Postoperatively, pain peaked on the first day (VAS: 7.8 ± 1.2), consistent with findings from Shahid *et al.,* [24], who reported similar acute postoperative pain levels in patients undergoing Ilizarov treatment. However, effective pain management strategies led to a significant reduction in VAS scores, decreasing to 5.2 ± 1.1 by the third day and progressively to 2.5 ± 0.9 by the seventh day ($p < 0.001$). The improvement in pain management reflects both the surgical technique and the benefits of early mobilization and rehabilitation. Notably, studies by Wang *et al.,* [25]. and Yu *et al.,* [26] corroborate the effectiveness of bone transport techniques in alleviating pain, with VAS scores consistently demonstrating significant improvement postoperatively. These reductions are attributed to the mechanical stability offered by hybrid systems and the gradual progression of bone healing. Effective pain management is a critical factor in patient compliance and satisfaction, contributing to the overall success of the

treatment. The ASAMI scores in this study highlight favorable outcomes, with excellent bone scores achieved in 93.75% of patients and good scores in 6.25%. Functional outcomes were similarly positive, with 62.50% achieving excellent scores and 31.25% good scores. These findings compare favorably with those of Bakhsh *et al.*, [27], who reported excellent bone outcomes in 66% and functional outcomes in 66% of cases. Notably, our results were similar to those reported by Zhang *et al.*, [15], where excellent functional outcomes were achieved in 62.5% of cases. Our findings emphasize the advantages of combining intramedullary nails with the Ilizarov method.

Limitations of the study

In our study, there was small sample size and absence of control for comparison. The study was conducted at a short period of time. Irregular follow-up after operation and high dropout rate were observed among the patients.

CONCLUSION AND RECOMMENDATIONS

This study highlights the effectiveness of hybrid bone transport techniques in managing long-bone defects across various surgical locations, achieving a high union rate and significant pain reduction. Clinical parameters, including docking and consolidation times, demonstrate the method's efficiency, though complications such as pin track infections and joint stiffness remain challenges. The distribution of nail types underscores the adaptability of the approach to patient-specific needs. To ensure effective gradual bone distraction, it is essential to incorporate regular physical exercise as part of the treatment regimen.

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