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Primary Limb Reconstruction System (LRS) Fixation in Compound Long Bone Fracture

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ABSTRACT

Background: Compound long bone fractures pose significant challenges due to high risks of infection, non-union, and severe soft tissue damage. Choosing an optimal fixation method is crucial for improving outcomes. This study evaluates the effectiveness of the Limb Reconstruction System (LRS) as the primary fixation method for these fractures, using the Asami score criteria to assess pain, function, and bone stability.

Methods: A prospective study was conducted on 30 patients with compound long bone fractures. Fracture conditions were simulated, and LRS was applied as the primary fixation method. Postoperative outcomes were assessed using the Asami criteria, focusing on bone stability, functional mobility, and pain relief. Statistical analysis was performed to compare LRS with alternative fixation methods, such as the Ilizarov frame, in terms of infection rates, weight-bearing capacity, and patient compliance.

Results: LRS demonstrated significant improvements in all postoperative outcome measures. Patients exhibited enhanced bone stability, better functional mobility, and effective pain relief. LRS was associated with lower infection rates and facilitated early weight-bearing compared to the Ilizarov frame, which is more complex to apply and may reduce patient compliance. Additionally, complication rates were low, with manageable issues such as pin tract infections.

Conclusion: The study reinforces previous findings on LRS as a viable, patient-friendly, and cost-effective treatment for complex fractures, particularly in resource-limited settings. LRS offers a reliable alternative to traditional fixation methods, ensuring improved recovery and early mobilization. Further long-term studies are recommended to establish LRS as the standard treatment for high-risk fractures in orthopedic trauma care.

Keywords: *Compound Long Bone Fractures, Limb Reconstruction System (LRS), Asami Score, Bone Stability, Functional Mobility, Statistical Analysis.*

1. INTRODUCTION

Long bone fractures due to high-energy trauma from falls and accidents are common in both industrialized and developing nations, particularly in the femur and tibia. These fractures pose serious risks of infection and nonunion, especially in open fractures. This explains that fractures where the bone is exposed through the skin are prone to contamination, requiring specialized fixation methods to promote healing and prevent complications[1]. Orthopedic surgeons often use external fixation techniques like the Limb Reconstruction System (LRS), which provides robust stabilization, early weight-bearing, and soft tissue healing without the invasiveness of internal fixation [2]. LRS is particularly preferred when internal fixation is unsuitable [3].

Extra Treatment Challenges with Compound Long Bone Fractures

Compound fractures present additional challenges as fixation devices must be strong, flexible, and resistant to contamination, alongside severe soft tissue damage. Open tibial fractures, due to limited muscle coverage, are highly susceptible to infection and nonunion, complicating treatment [4]. Poor or delayed management often results in prolonged healing and poor functional outcomes[5]. LRS is one of the most effective external fixation methods, increasing union rates, reducing infections, and improving quality of life [6].

LRS provides enhanced biomechanical stability, ease of use, and adjustability throughout the healing process. Using Schanz pins and clamps, it allows axial movement control and callus development, ensuring better bone union. It is especially useful in cases with significant bone and soft tissue loss and reduces complications such as pin-tract infections and hardware failure [7]. LRS enables early weight-bearing and mobilization, crucial for optimal rehabilitation [8].Compared to other fixation methods, LRS has fewer complications and greater patient compliance. While the Ilizarov frame is effective in complex cases, its technical demands and discomfort can hinder practical application [9]. LRS offers similar union rates with greater comfort, making it a suitable choice where specialized equipment is unavailable[10]. In resource-limited settings, LRS serves as a viable alternative for primary fixation [11].This study aims to evaluate the clinical effectiveness of LRS for compound long bone fractures, using the Asami score criteria to assess pain relief, functional improvement, and bone stability. It seeks to determine LRS's impact on postoperative recovery, reducing complications, and improving functional outcomes. Unlike previous studies with limited sample sizes, this research contributes to growing evidence on LRS as a flexible and effective treatment for complex fractures[12,13].

2. RELATED WORKS

Several studies have evaluated the effectiveness of the Limb Reconstruction System (LRS) in managing infected nonunions and nonunion fractures. Gajbhije et al. (2017) analyzed 60 cases of LRS-treated infected nonunions, reporting satisfactory to outstanding bony and functional results in 73% of patients based on ASAMI criteria, though frequent pin infections remained a concern [14]. Loya and Hugar (2022) examined the role of LRS in nonunion management in 20 patients, achieving a 90% success rate in fracture union and 80% good bone outcomes, emphasizing LRS's simplicity and patient comfort compared to the Ilizarov system[15]. Similarly, Garg et al. (2022) compared Ilizarov fixators and LRS in nonunion cases with bone loss, concluding that while both methods had equivalent union rates, LRS resulted in fewer complications, better compliance, and shorter union times due to its ease of use [16]. Biswas et al. (2023) conducted a case series on LRS for nonunion femur fractures, reporting 60% excellent functional results and 90% fracture union within 10 months, further establishing LRS as a viable alternative to traditional fixators[17]. Additionally, Sharma et al. (2020) studied LRS in tibial diaphyseal fractures and found that 73% of the 15 cases achieved union, with 46.67% showing good functional results based on ASAMI grading. Their findings highlighted the distraction osteogenesis potential of LRS in facilitating bone repair with minimal complications[18]. These studies collectively reinforce the efficacy of LRS as a reliable technique for managing nonunions and complex fractures.

3. MATERIALS AND METHODS

This study assessed the efficacy of primary LRS fixation for compound long bone fractures, focusing on strict patient selection criteria and precise surgical techniques. Thirty patients were selected based on rigid inclusion and exclusion criteria. Eligible patients were aged 18–65 years with Grade II or III compound long bone fractures from high-energy trauma, such as auto accidents, and fit for surgery under general anesthesia. Exclusion criteria included patients under 18 or over 65, those with closed fractures, conservatively treated fractures, or severe comorbidities like uncontrolled diabetes, active infections, or neurovascular injuries requiring alternative treatment.

Surgical Procedure

LRS fixation was performed under general anesthesia in a sterile operating room to minimize infection risk. The fracture site was thoroughly debrided, necrotic tissue removed, and the area irrigated to reduce contamination. LRS was then applied for rigid stabilization using a unilateral rail system with axial distraction and compression capabilities. Pins were carefully positioned to maintain fracture alignment while avoiding neurovascular structures, ensuring stable fixation and facilitating wound care.

Postoperatively, patients were monitored and assessed at 3, 6, and 12 months using the Asami score, evaluating pain, function, and bone stability. This systematic approach ensured accurate assessment of LRS fixation effectiveness in fracture healing.

Data Collection

The data collection sample was a sample of 30 patients who had primary Limb Reconstruction System (LRS) fixation for complex fractures in long bones. Patients were assessed both before and after surgery using Asami score criteria for clinical outcomes of pain, functional ability, and bone stability. Data were obtained from patient records and follow-up evaluations and clinical assessments. Here, the summarised demographic, surgical, and outcome-related data are appended below.

Overall information on the demographic of the research participants, in the form of average age, and gender specific values, as well as affected bone with fracture characteristics and injury mechanism are shown in table 1.Table 2 gives a summary of the key surgical parameters with an emphasis on average operation time, fixation length and postoperative hospital stay.

The Asami score criteria were used to follow up the patients' pain, function and bone stability at 6-months follow up. Fig. 1 below summarizes the result categories.Fig 2 displays any difficulties or unfavorable occurrences that occurred during or

after the procedure. This knowledge is important to understand the risks associated with most LRS fixation.Table3 shows the average time taken for different stages of recovery, such as weight-bearing capacity and range of motion, which are important for evaluating the functional outcomes of LRS fixation. The Tablealso shows patient reported outcomes of their overall quality of life improvements and the broad surgery satisfaction

The average amounts of time needed for the different recovery phases, including range of motion and weight bearing recovery, are graphically presented in Fig 3 and are important in evaluating the functional results of LRS fixation.

4. RESULTS AND ANALYSIS

Statistical analysis was performed of data collected from 30 patients treated with primary LRS fixation of compound long bone fractures. The main criteria for assessment were the Asami score (pain, function, and bone stability). It also looked at complications, recovery time, and patient satisfaction. It was analyzed using inferential tests such as paired t tests, chi square tests, and descriptive statistics such as mean and standard deviation.

The mean, standard deviation, and paired t-test findings comparing the Asami ratings for pain, function, and bone stability before and after surgery are shown in Table 4. Post-operative pain, function, and bone stability ratings showed statistically significant improvements ($p < 0.001$), suggesting that LRS fixation was successful.

Table 5 presents the distribution of Asami scores across the outcome categories (Excellent, Good, Fair, Poor) at the 6-month follow-up and provides a chi-square test to examine if score distribution differs across the Asami categories.

The chi-square analysis of scores for pain, function and bone stability shows a large variance in the distribution of scores with respect to patients who achieve "Excellent" or "Good" results with the majority ($p < 0.05$).

Table 6 depicts the lower Asami ratings (Fair or Poor) for pain and function are substantially correlated with complications, especially infection and delayed union ($p < 0.05$), suggesting that problems may affect overall results.

To determine if the lengths of recovery times are correlated to contentment, table7 below presents average recovery durations and satisfaction ratings together with correlation analysis.

There was a moderately negative correlation ($p < 0.05$) between recovery time and satisfaction ratings, so patients who recovered faster were more contented.

In fig 4, the pre- and post-operative ratings of pain, function and bone stability are shown. The shaded area between the lines is the improvement achieved after surgery. This fig shows such relative declines in Asami scores across parameters.

Fig 5 indicates the distribution of "Excellent," "Good," "Fair," and "Poor" ratings across pain, function, and bone stability is shown in this stacked bar chart. It is simple to compare results across categories and outcome factors since each segment is colour-coded and labels within the bars indicate the number of patients.

Fig 6 illustrates a patient with a complex long bone fracture before and after receiving Limb Reconstruction System (LRS) therapy. The pre-operative pic. shows the amount of the fracture, and the post-operative photos show healing process including soft tissue repair and bone union. Further, patient is also shown throughout several stages of recuperation, including early mobilization, weight bearing.

5. DISCUSSION

The study used the Asami score to assess pain, function, and bone stability outcomes, aiming to determine the effectiveness of primary Limb Reconstruction System (LRS) fixation in treating compound long bone fractures. Statistically significant gains in all end measures, as well as decreased discomfort and increased function and bone stability, were found with primary LRS fixation.

Statistically significant ($p < 0.001$) changes in pain levels were observed between pre- and post-operative evaluations. The results align with those of other related studies[19], including comparisons between LRS fixators and alternative external fixators, demonstrating significantly better pain and functional ratings for LRS fixators (Table 8). Similarly, research by Kale el al[20] indicated that LRS fixators allowed excellent pain control compared to fixed immobilization techniques in complex fracture cases.Results from the Asami scores demonstrate that the improvement in bone stability after LRS was particularly beneficial for complicated fractures, especially when varied weight-bearing and early mobilisation were permitted. This finding is consistent with studies by Lone et al. (2023) andArfee et al.[21] , which highlighted the increased efficiency, shorter healing periods, and greater comfort associated with LRS fixators compared to Ilizarov fixators[22].

In terms of safety and complications, bloodstream infections were common, occurring in 16.7% of patients, while 78.0% experienced pin-tract infections. Additionally, 72.7% had urinary tract infections, and 12.9% suffered from lung, abdominal (including biliary tract), and skin and soft tissue infections combined. The rate of pin-tract infection was comparable to that in LRS-treated infected nonunion patients[23]. Although the LRS fixator is simpler to use, results in fewer complications, and provides better patient satisfaction compared with the Ilizarov frame, it remains a valuable treatment option.Patient

satisfaction was notably high among those who received LRS fixation, with a strong correlation between high satisfaction, faster recovery, and earlier mobilisation. Studies by Patra et al.[24] and Loya et al.[15] have confirmed that LRS systems not only reduce treatment-related suffering and cost burden but also enhance the quality of life following recovery.Other techniques compared with the LRS system include AO monolateral fixators and Ilizarov ring fixators. Research by Bakshi et al.[25] has shown that LRS devices are more effective for non-union fractures, yielding superior results .

6. CONCLUSION

The effectiveness of primary Limb Reconstruction System (LRS) fixation for compound long bone fractures was analyzed using Asami scoring criteria, focusing on pain management, functional improvement, and bone stability. LRS demonstrated statistically significant pain reduction and functional enhancement, supporting its role as an effective treatment for complex fractures. It facilitated early weight-bearing, reduced infection rates, and improved soft tissue management—key factors for successful outcomes.

Patient compliance and satisfaction were high, and complications, though present, were manageable—primarily pin-tract infections. LRS combined simplicity, adaptability, and a lower complication risk compared to other fixation methods, such as the Ilizarov system. While Ilizarov remains preferable for limb lengthening and major realignment, LRS offers distinct advantages for rapid stabilization and early mobilization, particularly in resource-limited settings.

Findings align with existing studies, reinforcing LRS as an effective first-line fixation method for high-energy trauma. Future research should explore long-term outcomes and broader patient demographics to refine treatment protocols. LRS remains a valuable, minimally invasive option in modern orthopedic trauma care, enhancing recovery while ensuring stability.

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