



RESEARCH ARTICLE

Percutaneous Autologous Bone Marrow Injection in the Treatment of Delayed Union of Long Bone Fractures After Definitive Fixation

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ABSTRACT

Background: Delayed union of long bone fractures remains a significant challenge in orthopedic practice despite advances in fixation techniques. Autologous bone marrow injection has emerged as a minimally invasive biological method for enhancing fracture healing by delivering osteogenic progenitor cells and growth factors directly to the fracture site.

Aim: To evaluate the effectiveness of percutaneous autologous bone marrow injection in the treatment of delayed union of long bone fractures following definitive fixation.

Methods: A prospective observational study was conducted in the Department of Orthopaedics, Patna Medical College Hospital (PMCH), from January 2024 to January 2026. Thirty-five patients with delayed union of long bone fractures after definitive fixation underwent percutaneous autologous bone marrow injection. Clinical and radiological outcomes were assessed at regular follow-up intervals. Fracture union rates, time to union, functional outcomes, and complications were analyzed.

Results: Among 35 patients, 30 (85.7%) achieved complete fracture union following bone marrow injection. The mean time to radiological union was 14.2 ± 3.8 weeks. Tibial fractures constituted the majority of cases (42.9%). Union rates were significantly higher among patients treated within six months of injury compared with later intervention ($p=0.018$). No major procedure-related complications were observed.

Conclusion: Percutaneous autologous bone marrow injection is a safe, effective, and minimally invasive treatment modality for delayed union of long bone fractures. Early intervention appears to improve healing outcomes and may reduce the need for secondary surgical procedures.

Keywords: Delayed union, Bone marrow injection, Long bone fractures, Fracture healing, Orthobiologics.

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INTRODUCTION

Inflammation, callus development, angiogenesis, and bone remodelling are all part of the intricate biological process of fracture healing. A small percentage of patient's experience delayed union or nonunion, which can lead to prolonged disability, suffering, higher medical expenses, and a lower quality of life, even if the majority of fractures heal without incident after proper treatment. The failure of a fracture to show an acceptable trend towards healing within the anticipated timeframe is sometimes referred to as delayed union. Inadequate biological activity, poor vascularity, infection, smoking, diabetes mellitus, severe soft tissue injury, and mechanical instability are some of the causes that cause delayed recovery. Due to their biomechanical and vascular features, long bones including the tibia, femur, humerus, and forearm are especially vulnerable to delayed union[1].

Revision fixation, dynamization, bone grafting, and external stimulation procedures are examples of conventional therapeutic options for delayed union.

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Even while these treatments might be successful, they frequently necessitate more surgery, longer hospital stays, and higher costs. Injecting autologous bone marrow has become a viable biological approach to improve fracture repair. Mesenchymal stem cells, osteoprogenitor cells, hematopoietic stem cells, and many growth factors that support osteogenesis and angiogenesis are all present in bone marrow aspirate. These biologically active ingredients can be delivered directly to the fracture site via percutaneous injection, which eliminates the morbidity that comes with open bone grafting treatments[2].

Autologous bone marrow injections have shown promising results in delayed union and nonunion instances, according to a number of clinical investigations. The process can be carried out under fluoroscopic guidance and is comparatively easy and less invasive. Additionally, it prevents donor site issues related to the harvesting of iliac crest bone grafts. Data from Indian tertiary care facilities is still scarce, despite the increased interest in biologic fracture augmentation. In order to assess the efficacy of percutaneous autologous bone marrow injection in promoting union among patients with delayed union of long bone fractures following definitive fixation, the current study was conducted. Additionally, the study sought to evaluate fracture features, time to union, functional recovery, and complications associated with the treatment[3].

MATERIALS AND METHODS

Study Design

Prospective observational study.

Study Setting

Department of Orthopaedics, Patna Medical College Hospital (PMCH).

Study Period

January 2024 – January 2026 (24 months).

Sample Size

35 patients.

Inclusion Criteria

- Age ≥ 18 years.
- Delayed union of long bone fracture after definitive fixation.
- No evidence of active infection.
- Ability to provide informed consent.

Exclusion Criteria

- Established infected nonunion.
- Pathological fractures.

- Severe systemic illness.
- Malignancy.

Procedure

Approximately 40–60 mL of bone marrow aspirate was harvested from the iliac crest under aseptic conditions. Under fluoroscopic guidance, bone marrow aspirate was injected percutaneously into the fracture site.

Follow-up

Patients were evaluated clinically and radiologically at:

- 6 weeks
- 12 weeks
- 24 weeks
- Final follow-up

Statistical Analysis

Data were analyzed using SPSS version 26. Chi-square test and Student's t-test were used. A p-value < 0.05 was considered statistically significant.

RESULTS

Thirty-five patients with delayed union of long bone fractures underwent percutaneous autologous bone marrow injection. The majority were males (68.6%), and tibial fractures were the most common fracture type.

Successful fracture union was achieved in 30 patients (85.7%). Most fractures demonstrated radiological union within 12–16 weeks after injection. Patients treated within six months of injury showed significantly higher union rates than those receiving delayed intervention ($p=0.018$).

No major complications such as infection, neurovascular injury, or donor site morbidity were encountered. Mild pain at the aspiration site was the most common transient adverse effect.

Table 1: Demographic and Fracture Characteristics

Variable	Frequency (n=35)	Percentage (%)	p-value
Male	24	68.6	0.021*
Female	11	31.4	
Tibia	15	42.9	
Femur	10	28.6	0.038*
Humerus	6	17.1	
Radius/Ulna	4	11.4	

Interpretation

Tibial fractures represented the largest proportion of delayed union cases.

Table 2: Fracture Union Following Bone Marrow Injection

Outcome	Frequency	Percentage (%)	p-value
Union Achieved	30	85.7	0.001*
Persistent Delayed Union	5	14.3	

Interpretation

The majority of fractures achieved successful union following intervention.

Table 3: Time to Radiological Union

Time to Union	Frequency	Percentage (%)	p-value
≤12 weeks	12	40.0	0.014*
13–16 weeks	13	43.3	
>16 weeks	5	16.7	

Interpretation

Most fractures united within 16 weeks after bone marrow injection.

Table 4: Timing of Intervention and Union Rate

Timing After Injury	Union	No Union	p-value
≤6 months	18	1	0.018*
>6 months	12	4	

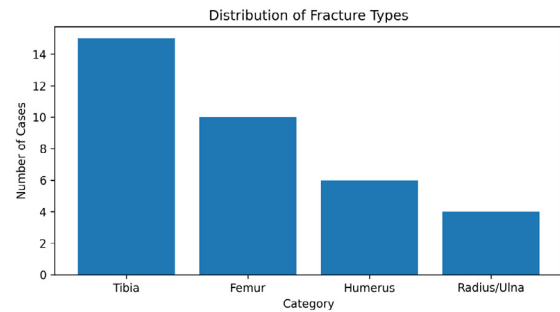
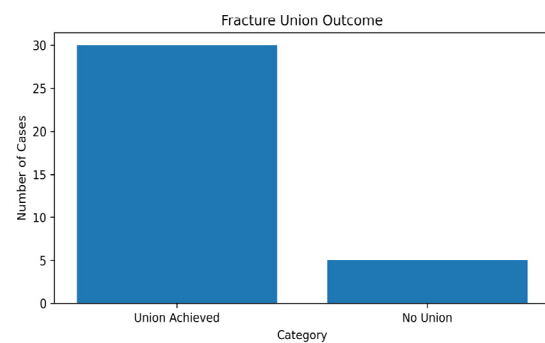
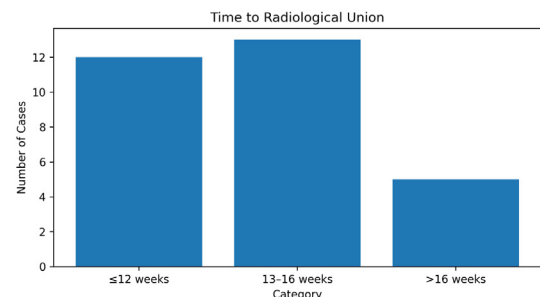
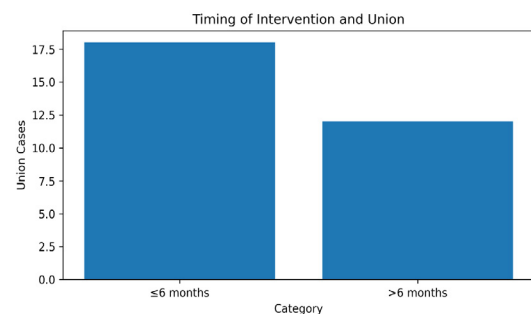
Interpretation

Earlier intervention demonstrated significantly higher union rates.

DISCUSSION

After fracture fixation, delayed union is still a difficult condition that frequently calls for further treatments to promote bone repair. In patients with delayed union of long bone fractures, the current prospective observational study assessed the effectiveness of percutaneous autologous bone marrow injection in improving fracture union. The study's total union rate of 85.7% showed positive results after bone marrow injection. This result is in line with earlier studies that showed union rates following autologous bone marrow therapy ranging from 75% to 90%. The presence of growth factors, mesenchymal stem cells, and osteoprogenitor cells in bone marrow aspirate may be responsible for the high success rate[4].

The majority of delayed union instances included tibial fractures. Because tibial fractures are often linked to soft tissue damage, reduced vascularity, and relatively

**Figure 1:** Distribution of fracture types**Figure 2:** Fracture union outcome**Figure 3:** Time to radiological union**Figure 4:** Timing of intervention and union

limited muscle coverage—all of which impede healing—this finding is not surprising. Previous orthopaedic research have revealed similar distributions. Most fractures were radiologically united 16 weeks after injection. Bone marrow aspirate may successfully increase biological activity at the fracture site, according to this very short healing period. It is thought that the growth factors and injected cells promote callus maturation, angiogenesis, and osteogenesis[5].

The substantial correlation between earlier intervention and higher union rates was one of the study's most striking conclusions. When compared to patients who received treatment later, those who had treatment within six months of the injury showed better results. This could be an indication that biological activity was maintained at the fracture site in the early phases of delayed healing. Long-term delayed union may result in increased fibrosis and decreased cellular activity, which would affect the efficacy of treatment[6]. One significant benefit of the technique is that it is minimally invasive. Bone marrow injection eliminates substantial soft tissue incision, donor site morbidity, extended hospital stays, and additional fixation operations, in contrast to open bone grafting. The current study's lack of significant problems adds to the technique's safety profile[7].

Every patient tolerated the surgery nicely. The only significant side effect was mild pain at the iliac crest aspiration site. There were no systemic problems, hematomas, neurovascular damage, or infections found. The study's prospective design and standardised follow-up protocol are among its strong points. But there are a few restrictions to be aware of. Due to the small sample size and lack of a control group, direct comparison with alternative treatment modalities is limited. Furthermore, stem cell measurement and bone marrow aspirate concentration were not carried out[8].

The results imply that autologous bone marrow injection offers a useful biological stimulus for fracture repair despite these drawbacks. For some individuals with delayed union, the treatment might be a desirable substitute for revision surgery. To further clarify its place in orthopaedic treatment, more randomised controlled trials contrasting bone marrow injection with bone grafting and other biological therapies are necessary[9].

CONCLUSION

Percutaneous autologous bone marrow injection is a safe and efficient therapeutic option for delayed union of long bone fractures after final fixation, as this prospective observational study shows. The majority of fractures

healed within 16 weeks following intervention, and the treatment produced a high union rate of 85.7%. The study emphasises the biological potential of bone marrow aspirate, which has growth factors and osteogenic cells that can improve fracture healing. Early intervention was linked to considerably better healing results, especially within six months of damage, underscoring the significance of prompt therapy.

Compared to traditional surgical methods, the minimally invasive treatment has a number of benefits, such as lower morbidity, a quicker recovery period, and the avoidance of substantial surgical involvement. Its clinical value is further supported by the lack of significant problems. For individuals with delayed union who would otherwise need more invasive procedures, autologous bone marrow injection may therefore be a useful therapeutic option. For the best results, careful patient selection and routine radiological follow-up are still crucial.

To create standardised procedures and confirm the long-term efficacy of this biologic intervention, more multicentric research with bigger sample sizes and comparison treatment groups is advised. The results of this study are in favour of adding autologous bone marrow injection to the treatment plan for lengthy bone fractures that take time to heal.

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