e-ISSN: 0976-822X, p-ISSN:2961-6042

Available online on http://www.ijcpr.com/

International Journal of Current Pharmaceutical Review and Research 2026; 18(6); 583-590

Original Research Article

Percutaneous Autologous Bone Marrow Grafting in Non-Union and Delayed Union of Long Bone Fractures: A Prospective Clinical and Radiological Study

Rakesh Kumar[1], Anubhav Chhabra[2], Ravi Sihag[3], Anurag Chhabra[4], Ashok Kumar[5], Pankaj Kamboj[6], Siddharth Tayal[7], Gajender Yadav[8], Lalit Dhaka[9], Anuj Kumar[10], Sonu[11], Sahil[12], Suryansh Agnihotri[13], Manas Sharma[14]

[1]Postgraduate, Dept of Orthopedics, MAMC Agroha, Hisar, India
[2]Assistant Professor, Dept of Orthopedics, MAMC Agroha, Hisar, India
[3]Assistant Professor, Dept of Orthopedics, MAMC Agroha, Hisar, India
[4]Senior Professor and Head of Dept, Dept of Orthopedics, MAMC Agroha, Hisar, India
[5]Professor, Dept of Orthopedics, MAMC Agroha, Hisar, India
[6]Senior Resident, Dept of Orthopedics, MAMC Agroha, Hisar, India
[7]Senior Resident, Dept of Orthopedics, MAMC Agroha, Hisar, India
[8]Postgraduate, Dept of Orthopedics, MAMC Agroha, Hisar, India
[9]Postgraduate, Dept of Orthopedics, MAMC Agroha, Hisar, India
[10]Postgraduate, Dept of Orthopedics, MAMC Agroha, Hisar, India
[11]Postgraduate, Dept of Orthopedics, MAMC Agroha, Hisar, India
[12]Postgraduate, Dept of Orthopedics, MAMC Agroha, Hisar, India
[13]Post graduate, Dept of Orthopedics, MAMC Agroha, Hisar, India
[14]Postgraduate, Dept of Orthopedics, MAMC Agroha, Hisar, India

Received: 16-04-2026 / Revised: 13-05-2026 / Accepted: 17-06-2026
Corresponding Author: Dr. Anurag Chhabra
Conflict of interest: Nil

Abstract

Background: Non-union and delayed union of long bone fractures remain a significant challenge in orthopaedics. Minimally invasive biological techniques such as percutaneous autologous bone marrow grafting have gained attention as an alternative to conventional bone grafting.

Aim: To evaluate the clinical and radiological outcomes of percutaneous autologous bone marrow grafting in non-union and delayed union of long bone fractures.

Methods: A prospective observational study was conducted on 30 patients aged ≥18 years presenting with aseptic delayed union or non-union of long bones. Bone marrow aspirate was harvested from the iliac crest and injected percutaneously at the fracture site. Patients were followed up clinically and radiologically at regular intervals up to 16 weeks using union scale score.

Results: The mean age of patients was 35.9±12.5 years, with male predominance (83.33%). Majority of cases involved femur (46.66%) and tibia (43.33%). Union was achieved in a significant proportion of patients, particularly in delayed union cases. Mean bone marrow volume injected was 18.03±4.95 ml. The procedure showed 80% success rates with no major complications.

Conclusion: Percutaneous autologous bone marrow grafting is a safe, minimally invasive, and effective technique for treating delayed union and selected cases of non-union, with good clinical and radiological outcomes.

Keywords: Bone Marrow Aspirate, Non-Union, Delayed Union, Fracture Healing, Minimally Invasive.
DOI: 10.25258/ijcpr.18.6.99

Introduction

Non-union and delayed union remain significant challenges in orthopaedic practice despite advances in surgical techniques and implant technology. Delayed union is generally defined as a failure of fracture healing within the expected time frame, typically between 3 to 6 months, while non-union is established when there is no radiological progression of healing for three consecutive months after a minimum of nine months since injury.[1] Aseptic non-unions are broadly classified into hypertrophic and atrophic types, with hypertrophic non-unions primarily requiring improved stability,

whereas atrophic non-unions often necessitate biological augmentation such as bone grafting.[2] Conventional treatment modalities, including autologous bone grafting, electrical stimulation, ultrasound therapy and bone transport techniques, have been widely usedbut each is associated with variable success rates and potential complications.[3] Autologous cancellous bone grafting, although considered the gold standard, is associated with donor-site morbidity, increased operative time, and risk of infection. Additionally, in previously operated fractures, implant removal and re-fixation may further compromise the vascularity of the fracture site, adversely affecting healing. Consequently, there has been growing interest in minimally invasive biological approaches that can enhance fracture healing while reducing surgical morbidity. Among these, percutaneous autologous bone marrow grafting has emerged as a promising technique. Bone marrow aspirate contains mesenchymal stem cells (MSCs), osteoprogenitor cellsand growth factors that contribute to osteogenesis and angiogenesis, thereby promoting fracture healing[4-5]. Recent advances in regenerative medicine have highlighted the role of biological augmentation using osteoconductive materials, osteoinductive factors and cellular therapies. Mesenchymal stem cells derived from bone marrow possess the ability to differentiate into osteoblasts, chondrocytes& adipocytes and play a crucial role in bone regeneration.[6-8] The success of fracture healing depends on the interaction of mechanical stability and biological factors, including an adequate vascular supply, cellular responseand a conducive scaffold for bone formation [9]. Despite encouraging results reported in the literature, there remains a paucity of robust data from the Indian population regarding the efficacy of percutaneous autologous bone marrow grafting. Therefore, the present study aims to evaluate the clinical and radiological outcomes of this minimally invasive technique in the management of non-union and delayed union of long bone fractures.

Material & Methods

This prospective observational study was conducted in the Department of Orthopaedics at Maharaja Agrasen Medical College, Agroha (Hisar), from the March 2024 to September 2025.Study was initiated after due approval fromInstitutional Ethics Committee (IEC).

Patients were selected based on predefined inclusion and exclusion criteria. The inclusion criteria comprised patients aged more than 18 years of either sex with clinical and radiological evidence of delayed union or non-union following fracture fixation or conservative management without prior bone grafting, fractures with acceptable alignment and good bony apposition at the fracture site with a gap of less than 10 mm.

Patients with pathological fractures, associated arterial or nerve injuries, fractures requiring repeat internal fixation or prior bone grafting, and infective delayed union or infective non-union were excluded from the study. Sample size was calculated based on a previous study by Bhutia et al [14] with a success rate of 86.67%, yielding a minimum of 27 cases; however, 30 patients were enrolled for better reliability.

All patients were admitted and the procedure was conducted in a clean operation theatre under strict aseptic precautions. An intravenous line was secured and prophylactic intravenous antibiotics were administered prior to the procedure. The procedure was performed under local anesthesia, regional anesthesia, or short general anesthesia.

The site of bone marrow aspiration (anterior iliac crest) was painted and draped along with the site of delayed union or non-union. One or two 14/16-gauge needle were inserted in or around the recipient site through safe corridors under C-arm guidance. This was done prior to bone marrow aspiration to prevent clotting of the aspirate and simultaneous immediate injection of bone marrow.

The bone marrow aspirate was collected in rations and injected simultaneously through the already placed needles at the delayed union or non-union site, with volumes ranging from 10–30 mL. Post-procedure, a sterile dressing and compression bandage were applied. Patients received oral antibiotics for 3 days and analgesics for one week.

Patients were followed up clinically and radiologically at 4, 8, 12, and 16 weeks. Clinical assessment included pain, tenderness, and abnormal mobility, while radiological evaluation focused on callus formation. Union was assessed using the union scale score[5] and repeat bone marrow injection was performed in selected cases.

Figure 1: Jamshidi insertion (Anterior iliac crest)

Figure 2: Recipient site (Femur NU)

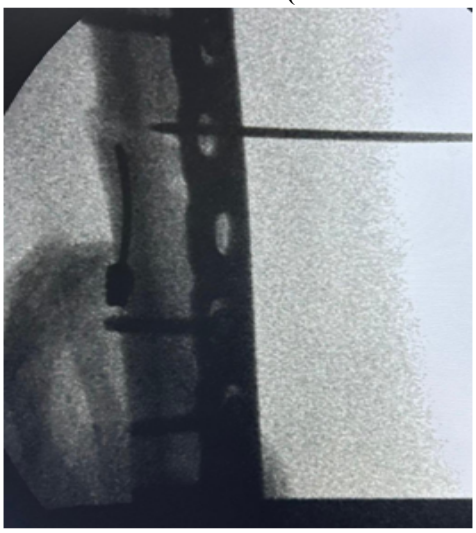

Figure 3: C-arm imagewith needles at NU site

Figure 4: Bone marrow aspiration

Figure 5: Bone marrow injection at recipient site

Results

A total of 30 patients were included in the study with no loss to follow-up. The mean age was 35.9 ± 12.5 years (range: 21–72 years), with a clear male predominance (83.33%). The most common mode of injury was road traffic accident (96.66%). The femur (46.66%) was the most frequently involved bone, followed by the tibia (43.33%). Most fractures were initially managed with intramedullary nailing (63.33%), followed by plating (20%) and conservative treatment (10%).

Percutaneous autologous bone marrow grafting resulted in satisfactory clinical and radiological outcomes. Union was achieved in 81.18% of tibial non-unions and 100% of delayed union tibia cases.

Femoral non-union demonstrated a union rate of 77.77%, while delayed union femur showed a comparatively lower union rate of 50%. Overall, union was achieved in 24 out of 30 cases (80%). Higher union rates were observed in fractures with stable fixation.

A significant positive correlation was observed between fracture union and Union Potential Grading (UPG)[5] score, with union rates increasing from 50% at a score of 10 to 100% at scores of 12 and 14.

Table 1: Distribution of patients according to UPG score and union outcome

UPG Score	No. of patients	United	Union(%)
10	2	1	50
11	11	8	72.7
12	1	1	100
13	13	11	84.6
14	3	3	100

Similarly, higher volumes of injected bone marrow aspirate (21–30 ml) were associated with improved union rates compared to lower volumes.

Table 2: Distribution of patients according to bone marrow aspirate volume relation to union

Bone marrow injected	Recipient bone	No. of patients	United	Union(%)
0-10ml	None	0	0	0
>10-20ml	Femur	6	3	50
	Tibia	11	9	81.81
	Humerus	1	0	0
	Ulna	1	1	100
>20-30ml	Femur	8	8	100
	Tibia	2	2	100
	Humerus	1	1	100

Radiological callus formation was observed in the majority of patients by 8–12 weeks. In 9 patients, the procedure was repeated, following which 3 patients showed appearance of radiological callus formation within 4 weeks after the second injection.

Table 3: Distribution of patients according to appearance of callus

Appearance of callus	Number of patients	Number of procedures
8 weeks	14	1
12 weeks	9	1
16 weeks (4 weeks of 2nd procedure)	3	2

Union scale score improves significantly, increasing from a mean of 3.86±0.5 at 4 weeks, 4.56±0.56 at 8 weeks, 5.06±0.73 at 12 weeks, 5.76±0.97 at 16 weeks. In cases with an intramedullary nail or plate in situ, a mobility score of 3 was assigned, as assessment of abnormal mobility was not possible due to the presence of internal fixation.

Table 4: Distribution of patients according to union score

Union Scale Score	Mean
4 weeks	3.86±0.50
8 weeks	4.56±0.56
12 weeks	5.06±0.73
16 weeks	5.76±0.97

Following percutaneous autologous bone marrow grafting, satisfactory clinical and radiological union was achieved in most cases regardless of the initial treatment modality.

Table 5: Distribution of Patients According to Outcome based on initial treatment

Initial Treatment	Bone	No. of patients	United	Union(%)
Conservative	Tibia	1	1	100
	Humerus	1	1	100
	Ulna	1	1	100
CRIF with nailing	Tibia	9	7	77.77
	Shaft of femur	9	7	77.77
	Sub-trochantric femur	1	1	100
CRIF with TENS	Tibia	1	1	100

ORIF with plating	Tibia	1	1	100
	Shaft of femur	2	1	50
	Supracondylar Femur	1	1	100
	Medial condyle femur	1	1	100
	Humerus	1	0	0
External fixator	Tibia	1	1	100

The procedure was associated with minimal complications. Mild pain and local tenderness at the donor or recipient site were noted in a few patients during the early postoperative period, which resolved with conservative management. No major complications such as infection, neurovascular injury, or fat embolism were observed.

Table 6: Distribution of patients according to their complications

Complications	3 Days	Within 1 week after procedure	4 weeks	12 weeks	16 weeks
Pain	5	2	0	0	0
Local Site tenderness	2	0	0	0	0
Limitation of movement	0	0	0	0	0
Infection	0	0	0	0	0

CASE 7

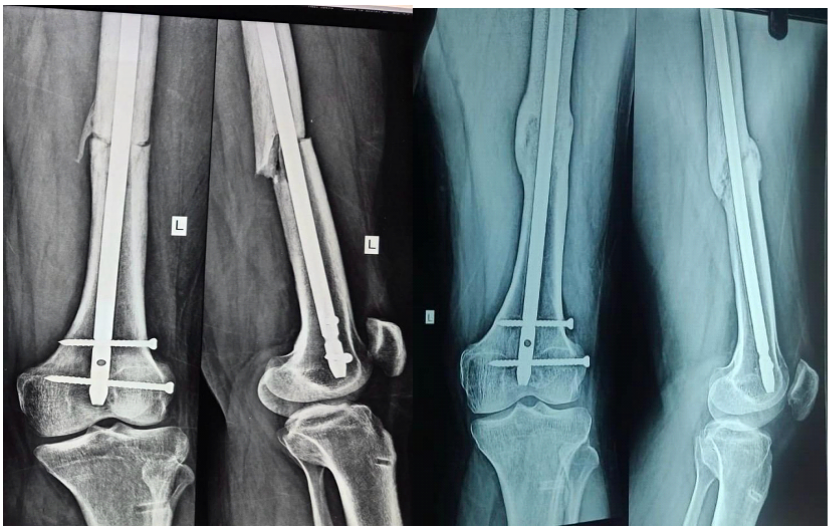

Figure 6A: Pre union x-ray **Figure 6B: Post union x-ray**

CASE 11

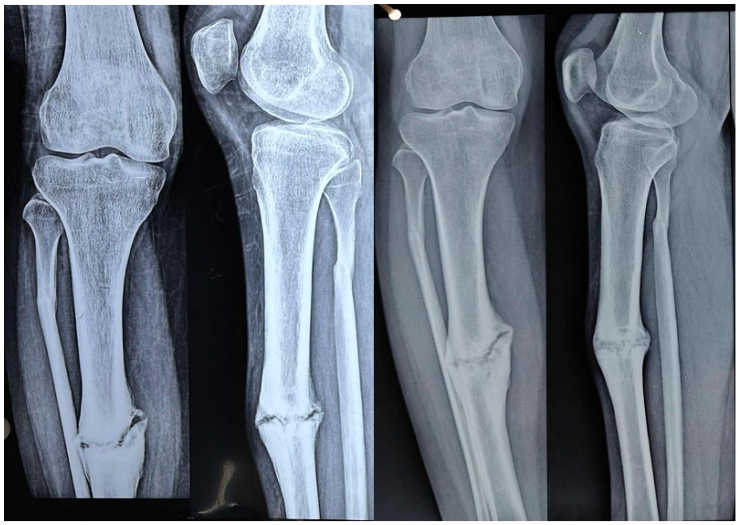

Figure 7A: Pre op x-ray **Figure 7B: Post op x-ray**

CASE 18

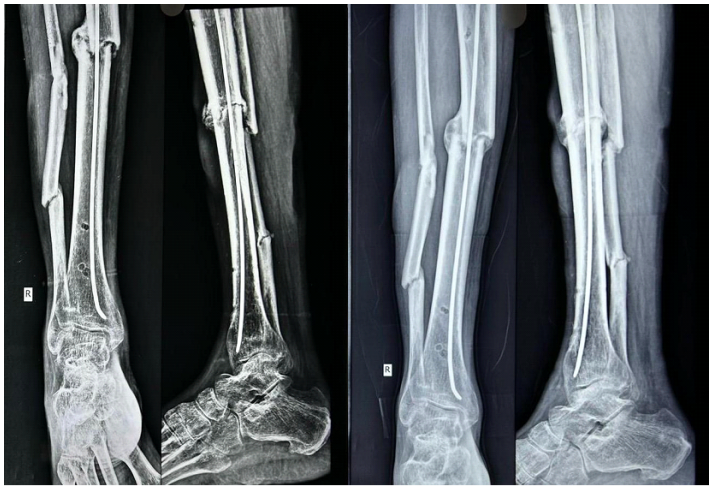

Figure 8A: Pre op x-ray **Figure 8B: Post op x-ray**

CASE 27

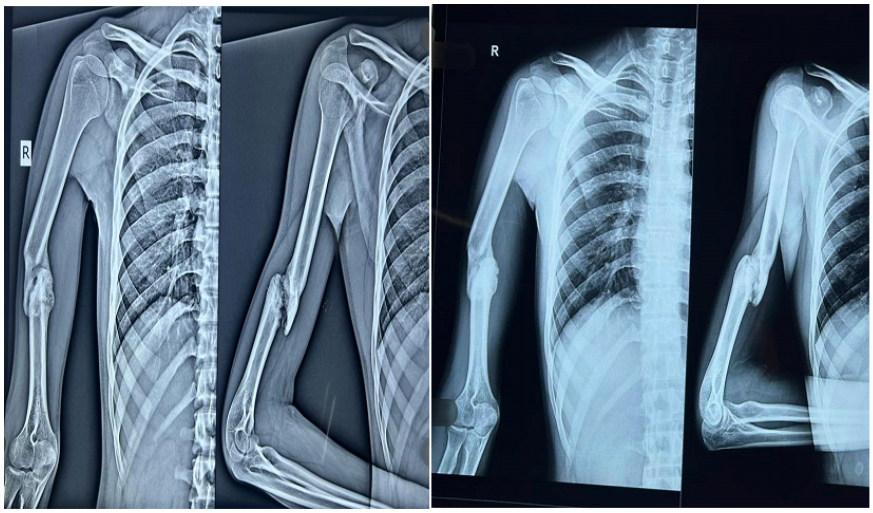

Figure 9A: Pre op xray **Figure 9B: Post op xray**

Discussion

Fracture healing is a complex process dependent on both mechanical stability and biological factors, including osteoinductive growth signals, vascularity and the presence of mesenchymal stem cells [9-11]. Bone marrow aspirate contains osteoprogenitor cells and growth factors that enhance osteogenesis and promote fracture healing. Hernigou et al[12] and Bhargava et al [5] reported favorable outcomes with this technique, emphasizing the importance of progenitor cell concentration and early intervention in improving union rates.

In the present study, an overall union rate of 80% was achieved, which is comparable to previously reported rates ranging from 75% to 95%. Kaseem et al [3], Bhargava et al[5] and Braly et al[13] have reported similar union rates in their respective studies. Better outcomes were observed in delayed union compared to established non-union, suggesting that early biological augmentation plays a critical role in fracture healing. Additionally, fracture union showed a positive correlation with increasing Union Potential Grading (UPG) score, indicating that fractures with better biological potential respond more favorably to treatment, as also highlighted by Bhargava et al [5]. A similar trend was observed with increasing volume of bone marrow injected, supporting a dose–response relationship reported by Bhutia et al [14].

The procedure was associated with minimal complications, with only mild transient pain at the donor and recipient sites and no major adverse events such as infection, neurovascular injury or fat embolism [15-17]. These findings are consistent with previous reports byKarthik et al [18] and others, which have demonstrated the safety of this technique. Furthermore, progressive improvement in union scale score observed during follow-up reflects continuous clinical and radiological healing, similar to findings reported by Bhargava et

al [5]. Satisfactory union was achieved across various initial treatment modalities, including conservative management, intramedullary nailing, plating, TENS, and external fixation, provided that fracture alignment and mechanical stability were maintained. However, the study is limited by a relatively small sample size and lack of a control group. Larger randomized controlled trials are required to validate these findings and establish standardized protocols. Despite these limitations, percutaneous autologous bone marrow grafting appears to be a safe, effective and practical alternative to open bone grafting in appropriately selected cases.

Conclusion

Percutaneous autologous bone marrow aspirate injection is a safe, minimally invasive, and biologically effective technique for the management of delayed union and selected cases of non-union of long bone fractures. In the present study, an overall fracture union rate of 80% was achieved, comparable to outcomes reported in the literature. The technique provides a favourable biological stimulus for fracture healing, as evidenced by progressive radiological callus formation and improvement in union scale scores during follow-up.

Better outcomes were observed in fractures with higher Union Potential Grading scores, underscoring the importance of an adequate biological environment. Additionally, higher volumes of injected bone marrow aspirate were associated with improved healing outcomes.Early intervention with bone marrow aspirate injection following delayed union was associated with more favourable healing outcomes, suggesting that earlier application of the procedure may enhance fracture union rates. The procedure demonstrated an excellent safety profile with minimal complications and no major adverse events. Therefore, it can be considered an effective adjunct that may reduce the need for more extensive surgical interventions.

However, its use is limited in cases with infection, unstable fixation, deformity, or limb shortening. Large-scale randomized studies are required to validate its efficacy and establish standardized treatment protocols.

References

1. Cunningham BP, Brazina S, Morshed S, Miclau III T. Fracture healing: A review of clinical, imaging and laboratory diagnostic options. Injury. 2017 Jun 1;48:S69-75.
2. Panagiotis M. Classification of non-union. Injury. 2005 Nov 1;36(4):S30-7.
3. Kassem MS. Percutaneous autogenous bone marrow injection for delayed union or non-union of fractures after internal fixation. Acta Orthop Belg. 2013 Dec 1;79(6):711-7.
4. Pecina M, Vukicevic S. Biological aspects of bone, cartilage and tendon regeneration. Int Orthop. 2007 Dec;31(6):719-20.
5. Bhargava R, Sankhla SS, Gupta A, Changani RL, Gagal KC. Percutaneous autologus bone marrow injection in the treatment of delayed or nonunion. Indian J Orthop. 2007 Jan;41(1):6.
6. Emara KM, Diab RA, Emara AK. Recent biological trends in management of fracture non-union. World J Orthop. 2015 Sep 18;6(8):623-8.
7. Einhorn TA. Enhancement of fracture-healing. J Bone Joint Surg Am. 1995 Jun 1;77(6):940-56.
8. Qin Y, Guan J, Zhang C. Mesenchymal stem cells: mechanisms and role in bone regeneration. Postgrad Med J. 2014 Nov;90(1069):643-7.
9. Carofino BC, Lieberman JR. Gene therapy applications for fracture-healing. J Bone Joint Surg Am. 2008 Feb 1;90(2):99-110.
10. Nejadnik H, Hui JH, Feng Choong EP, Tai BC, Lee EH. Autologous bone marrow-derived mesenchymal stem cells versus autologous chondrocyte implantation: an observational cohort study. Am J Sports Med. 2010;38(6):1110–1116.
11. Imam MA, Mahmoud SSS, Holton J, Abouelmaati D, Elsherbini Y, Snow M. A systematic review of the concept and clinical applications of bone marrow aspirate concentrate in orthopaedics. SICOT J. 2017;3:17.
12. Hernigou P, Homma Y, FlouzatLachaniette CH, Poignard A, Chevallier N, Rouard H. The use of percutaneous autologous bone marrow transplantation in nonunion and avascular necrosis of bone. J Bone Joint Surg Br. 2005;87(7):896–902.
13. Braly HL, O'Connor DP, Brinker MR. Percutaneous autologous bone marrow injection in the treatment of distal meta-diaphyseal tibial nonunions and delayed unions. J Orthop Trauma. 2013;27(9):527–534.
14. Bhutia KU, Bary AA, Singh AK, Singh AM, Raghuvanshi R, Hmar C. Role of percutaneous autologous bone marrow injection in treatment of delayed union and nonunion of long bones. J Dent Med Sci. 2015;14:7–13.
15. Husebye EE, Lyberg T, Roise O. Bone marrow fat in the circulation: clinical entities and pathophysiological mechanisms. Injury. 2006;37(Suppl 4):S8–S18.
16. Orlowski JP, Julius CJ, Petras RE, Porembka DT, Gallagher JM. The safety of intraosseous infusions: risks of fat and bone marrow emboli to the lungs. Ann Emerg Med. 1989;18(10):1062–1067.

17. Jager M, Jelinek EM, Wess KM, Scharfstadt A, Jacobson M, Kevy SV, Krauspe R. Bone marrow concentrate: a novel strategy for bone defect treatment. Curr Stem Cell Res Ther. 2009;4(1):34–43.

18. Karthik RC, Dayanand BB, Basavaraj MK. To study the union rates and complications of percutaneous bone marrow injection in delayed union of long bone fractures: a prospective study. Int J Orthop Sci. 2023;9(3):34–39.