Journal of Clinical and Nursing Research, 2026, Volume 10, Issue 1
http://ojs.bbwpublisher.com/index.php/JCNR
Online ISSN: 2208-3693
Print ISSN: 2208-3685

Research on the Efficacy of Autologous Periosteum Graft Combined with PRP in the Treatment of Long Bone Fractures in the Extremities

Xiang Chen

Santai County People's Hospital, Mianyang 621100, Sichuan, China

Abstract: *Objective*: To analyze the clinical application value of autologous periosteum graft combined with platelet-rich plasma (PRP) in the treatment of long bone fractures in the extremities. *Methods*: A total of 40 patients with long bone fractures in the extremities admitted to Santai Hospital Affiliated to North Sichuan Medical College from January 2023 to January 2025 were included, including cases of upper extremity forearm fractures and lower extremity femoral and tibial fractures. The patients were evenly divided using a random number table, with the control group undergoing open reduction and internal fixation (ORIF) combined with autologous periosteum graft, and the observation group undergoing ORIF, autologous periosteum graft, and PRP injection. Surgical indicators, complication rates, excellent fracture healing rates, functional satisfaction, and joint range of motion were compared between the two groups. *Results:* The surgical indicators in the observation group were similar to those in the control group ($p > 0.05$). The complication rate in the observation group was lower than that in the control group, while the excellent fracture healing rate and functional satisfaction were higher in the observation group ($p < 0.05$). *Conclusion:* Autologous periosteum graft combined with PRP technology is safe and reliable for the treatment of long bone fractures in the extremities, with satisfactory clinical outcomes.

Keywords: Periosteum graft; Long bones of the extremities; PRP; Complication rate; Fracture healing

Online publication: Feb 11, 2026

1. Introduction

Patients with fractures of the long bones of the extremities are at a higher risk of developing nonunion after surgery. Factors such as complex fractures caused by high-energy violence, infection, and improper internal fixation methods for fractures can all potentially lead to fracture nonunion. The treatment of fracture nonunion is time-consuming and challenging, representing a significant dilemma in current orthopedic trauma care [1,2]. Therefore, to enhance the likelihood of primary fracture healing, this study treated long bone fractures with high-risk factors for nonunion by combining autologous periosteal transplantation with Platelet-Rich Plasma (PRP) on the basis of internal fracture fixation. A retrospective analysis was conducted on cases from our hospital from

January 2023 to January 2025, and the report is presented as follows.

2. Data and methods

2.1. General information

Forty patients with fractures of the long bones of the extremities admitted to Santai Hospital Affiliated to North Sichuan Medical College from January 2023 to January 2025 were selected and evenly divided using a random number table into a control group and an observation group, with 20 patients in each group. In the control group, there were 10 males and 10 females, aged between 20 and 64 years, with an average age of (42.65 ± 4.18) years. In the observation group, there were 11 males and 9 females, aged between 18 and 62 years, with an average age of (42.30 ± 4.29) years. There were no significant differences in the data between the two groups ($p > 0.05$).

2.1.1. Inclusion criteria

(1) Patients with comminuted fractures of the ulna, radius, tibia, or femur who are planned to undergo surgical treatment;
(2) Patients aged between 18 and 65 years;
(3) Patients with complete postoperative follow-up for more than 6 months.

2.1.2. Exclusion criteria

(1) Patients with extremely poor cardiopulmonary function;
(2) Patients unwilling to participate in the study;
(3) Patients with surgical contraindications.

2.2. Methods

2.2.1. Control group

(1) Preparation of PRP

Blood Collection and Anticoagulation: After routine disinfection of the skin, use a blood collection needle along with a dedicated separation tube to collect venous blood up to the 8 mL mark (black indicator). Immediately after blood collection, gently invert the test tube 10–20 times to ensure thorough mixing of the anticoagulant with the blood. If collecting multiple tubes, complete the inversion and mixing simultaneously with the assistance of an assistant, ensuring gentle handling throughout the process to prevent hemolysis.

First Centrifugation and Plasma Separation: Place the balanced blood collection tubes symmetrically in the centrifuge and centrifuge at a speed of 3500–4000 rpm for 5–10 minutes. After the machine stops, remove the tubes and let them stand for 3–5 minutes to ensure full precipitation of platelets. Then, use a 10 mL syringe equipped with an elongated needle (≥ 7 cm) to aspirate the supernatant layer by layer from top to bottom, which is the platelet-poor plasma (PPP), until approximately 1–2 mL of serum remains.

(2) Surgical procedure

Taking the tibial intramedullary nailing operation as an example, after achieving the desired anesthetic effect, apply and inflate a pneumatic tourniquet. Position the patient in a supine position and use a parapatellar approach. Make a longitudinal incision along the medial side of the patellar tendon to open the expansion portion of the extensor retinaculum. Use retractors to pull the patellar tendon laterally and protect it with a protective sleeve. Select the intersection point approximately 3 cm medial to the tibial crest and the anterior margin of the tibial plateau as the needle entry point. Use an awl to create an opening, insert a guidewire, and drill through the cortical bone along the guidewire using a trephine. Expand the medullary canal with a flexible reamer, insert an intramedullary nail of appropriate size and length, lock the distal screws, and use an aiming device to lock the proximal screws. Finally, install the end cap.

(3) Periosteal preparation

Taking the ipsilateral tibia as an example. Make a longitudinal incision centered on the fracture site, exposing the skin and subcutaneous tissue, and create an appropriately sized incision. Bluntly dissect the subcutaneous tissue to reach the medial aspect of the tibia. Given that the periosteum in the anteromedial region of the tibia is relatively thick, while the lateral periosteum is thinner, the anteromedial region is typically chosen for harvesting. Incise the periosteum longitudinally along the tibial crest and the anterolateral margin of the diaphysis, and make a transverse incision at the distal end of the initial incision to form a rectangular periosteal flap. The area of this flap should be 10–15% larger than the bone defect area. Subsequently, use a periosteal elevator to gently elevate the entire layer of periosteum from the distal to the proximal end, keeping it closely adhered to the bone surface. Rotate the vascularized periosteal flap to cover approximately one-half to two-thirds of the fracture circumference, and then suture the periosteum to the adjacent soft tissue with a few stitches using antibacterial Vicryl sutures for fixation.

2.2.2. Observation group

PRP Resuspension and Collection: Shake the remaining serum portion approximately 20–30 times to thoroughly wash off the platelets adhering to the tube walls and separating gel. Finally, invert the tube and use a 3 mL syringe to extract all the liquid from the tube, which is the required platelet-rich plasma (PRP). The surgical procedure and periosteal preparation methods are the same as those in the control group. After suturing the periosteum and adjacent soft tissues, irrigate the wound cavity with normal saline and inject the prepared PRP into the wound cavity, leaving a drainage tube in place.

Within 24 hours after surgery, all patients are routinely administered intravenous cefuroxime sodium (1.5 g, q8h) to prevent infection. Oral analgesics (celecoxib capsules + tramadol hydrochloride sustained-release tablets) are also given. For patients undergoing lower limb surgery, low molecular weight heparin calcium (4000 IU) is routinely administered subcutaneously starting 12 hours after surgery, once daily. The plasma drainage tube is removed on the second day after surgery.

2.3. Observation indicators

(1) Surgical indicators

Observe indicators such as surgical time and intraoperative blood loss.

(2) Complication rate

Observe the probability of complications such as skin infection around the incision, skin necrosis, nonunion, malunion, vascular nerve injury, and ipsilateral intermuscular venous thrombosis.

(3) Excellent and good rate of fracture healing

Patients are followed up in the outpatient clinic 12 months after surgery, and anteroposterior and lateral DR images of the long bone fracture site are taken to assess fracture healing. Excellent indicates no abnormalities such as pain or infection, no malunion, adjacent joint mobility exceeding 90% of the healthy side, or normal mobility, and normal daily activity ability; good indicates mild pain or mild infection, no malunion, adjacent joint mobility exceeding 70% to 90% of the healthy side, and basically normal daily activity ability; poor indicates severe pain and infection, malunion, adjacent joint mobility less than 70% of the healthy side, and failure to recover daily activity ability.

(4) Functional satisfaction

A self-made functional satisfaction scale was used, covering aspects such as joint range of motion and weight-bearing walking, with a total score of 100 points. Scores exceeding 75 points indicated high satisfaction, scores between 40 and 75 points indicated basic satisfaction, and scores below 40 points indicated dissatisfaction.

2.4. Statistical analysis

Data processing was conducted using SPSS 28.0 statistical software. Count data were expressed as [n/%], and the chi-square (c^2) test was used for analysis. Measurement data were tested for normal distribution using the K-S method and expressed as [$\bar{x} \pm s$]. Comparisons between groups were made using the independent samples t-test, while comparisons within groups were made using the paired *t*-test. A *p*-value less than 0.05 was considered statistically significant.

3. Results

3.1. Comparison of surgical indicators between the two groups

The surgical indicators in the observation group were similar to those in the control group ($p > 0.05$), refer **Table 1**.

Table 1. Comparison of surgical indicators between the two groups [$\bar{x} \pm s$]

Group	Number of cases (n)	Operative time (min)	Intraoperative blood loss (mL)
Observation group	20	108.67 ± 9.74	101.98 ± 7.71
Control group	20	110.81 ± 9.87	103.86 ± 6.98
t-value	-	0.690	0.808
p-value	-	0.494	0.424

3.2. Comparison of complication rates between the two groups

The complication rate in the observation group was lower than that in the control group ($p < 0.05$) (see **Table 2**).

Table 2. Comparison of complication rates between the two groups [n/%]

Group	Number of cases (n)	Incision infection	Skin necrosis	Nonunion	Malunion	Vascular/nerve injury	Ipsilateral intermuscular vein thrombosis	Overall incidence rate
Observation group	20	0	0	0	0	0	1 (5.00)	5.00 (1/20)
Control group	20	1 (5.00)	1 (5.00)	1 (5.00)	0	1 (5.00)	2 (10.00)	30.00 (6/20)
χ^2-value	-	-	-	-	-	-	-	4.329
p-value	-	-	-	-	-	-	-	0.038

3.3. Comparison of excellent and good fracture healing rates between the two groups

The excellent and good fracture healing rate in the observation group was higher than that in the control group ($p < 0.05$), refer **Table 3**.

Table 3. Comparison of excellent and good fracture healing rates between the two groups [n/%]

Group	Number of cases (n)	Excellent	Good	Poor	Excellent/good rate
Observation group	20	12 (60.00)	7 (35.00)	1 (5.00)	95.00 (19/20)
Control group	20	7 (35.00)	6 (30.00)	7 (35.00)	65.00 (13/20)
χ^2-value	-	-	-	-	5.625
p-value	-	-	-	-	0.018

3.4. Comparison of functional satisfaction between the two groups

Functional satisfaction in the observation group was higher than that in the control group ($p < 0.05$). (see **Table 4**).

Table 4. Comparison of functional satisfaction between the two groups [n/%]

Group	Number of cases (n)	Excellent	Good	Poor	Excellent/good rate
Observation group	20	11 (55.00)	7 (35.00)	2 (10.00)	90.00 (18/20)
Control group	20	6 (30.00)	6 (30.00)	8 (40.00)	60.00 (12/20)
χ^2-value	-	-	-	-	4.800
p-value	-	-	-	-	0.029

4. Discussion

During the process of fracture healing, the integrity of the periosteum is crucial for successful bone repair. The periosteal tissue at the fracture site of long bone diaphysis is often damaged due to trauma, leading to insufficient local blood supply after surgery [3]. The introduction of exogenous osteogenic growth factors can selectively recruit and activate osteogenic precursor cells within the periosteum, promoting their proliferation and differentiation into osteoblasts. This, in conjunction with the body's inherent repair mechanisms, facilitates the acceleration of fracture and bone defect healing. Based on this, periosteal transplantation techniques have increasingly become an important clinical option for treating non-union fractures. Periosteal transplantation, a method involving the harvesting of autologous periosteum or local periosteal inversion and suture, is fixed to the cleaned-out area of articular cartilage lesions or defects, or to areas with significant periosteal loss due to fracture reduction and avulsion, has been studied in animal models and clinical applications in recent years for repairing cartilage injuries and periosteal defects [4].

Platelet-rich plasma (PRP) is a platelet suspension obtained through centrifugation and concentration. Its primary function lies in the release of various high-concentration growth factors upon activation, such as TGF-β, IGF, bFGF, and PDGF, which initiate and regulate the tissue repair process. These biologically active substances not only promote the repair and regeneration of bone and cartilage tissues but also stimulate peripheral angiogenesis. Based on these biological properties, PRP has been widely used in the medical field for the treatment of fractures, bone tissue necrosis, and degenerative joint diseases [5]. Numerous clinical studies have confirmed that

PRP demonstrates remarkable efficacy in promoting bone healing. Its application not only accelerates new bone formation in areas of bone defects but also helps improve the mechanical quality and structure of the newly formed bone. It is effective in promoting the healing of limb bones and reducing the incidence of nonunion. Compared to single surgical intervention, the synergistic treatment of PRP combined with surgery can more effectively promote postoperative healing of limb fractures and significantly elevate the levels of bone metabolism markers in patients' serum, including osteocalcin, bone-specific alkaline phosphatase, and the concentration of β-I type collagen carboxy-terminal peptide [6].

Advantages of periosteal transplantation:

(1) The periosteal flap is rich in perforating and communicating vascular networks, ensuring abundant blood supply.

(2) A large area of the periosteal flap can be harvested, with options available from both the medial and lateral sides of the tibia.

(3) It does not cause damage to the main vessels or affect the blood supply to the calf muscles.

(4) It promotes osteogenesis, especially when a vascularized periosteal flap is used, which provides a rich blood supply and increases local oxygen content, accelerating the differentiation and proliferation of mesenchymal stem cells into osteoblasts, ultimately leading to the formation of new bone [7].

(5) It accelerates the formation of callus by increasing the differentiation and proliferation of a large number of osteoprogenitor cells into osteoblasts. The germinal layer of the periosteum contains a large number of osteoprogenitor cells, which ultimately form new callus.

(6) It undergoes remodeling to form hard cortical bone. The harvested tibial periosteal flap is rotated and repositioned, with the cancellous bone surrounded by a periosteum rich in blood supply, facilitating the re-establishment of blood circulation at the fracture site and ultimately leading to the formation of new cortical bone.

(7) The periosteum provides abundant blood vessels, conferring strong anti-infective capabilities and reducing the risk of infection [8].

This study employed autologous periosteal transplantation combined with PRP injection therapy for the treatment of long bone shaft fractures, utilizing PRP as a supplementary intervention to the core treatment. The results indicated that the surgical indicators in the observation group were comparable to those in the control group ($p > 0.05$). The complication rate in the observation group was lower, while the excellent fracture healing rate and functional satisfaction were higher than those in the control group ($p < 0.05$). The analysis revealed that this combined therapy, by activating biologically active factors released from platelets, stimulates the directional differentiation of bone marrow mesenchymal stem cells in cancellous bone with periosteum, leading to their transformation into chondrocyte lineage and subsequently accelerating the formation of cartilage matrix [9]. This synergistic effect not only significantly shortened the callus mineralization period but also optimized the cartilage repair process, effectively reducing postoperative adverse events and ultimately achieving more reliable clinical outcomes. Based on clinical case observations at our hospital, for comminuted fractures of the extremities' shafts with a high likelihood of nonunion, adjacent periosteal transplantation to the fracture site combined with PRP intra-wound cavity injection can enhance fracture healing rates and reduce complication rates, outperforming simple internal fixation surgery [10]. The short-term follow-up results of autologous periosteal transplantation combined with PRP for long bone fractures were satisfactory. However, due to the small sample size and limited follow-up duration in this study, the long-term efficacy and safety require further evaluation through extended follow-up and expanded sample sizes.

5. Conclusion

In summary, the combined application of autologous periosteal transplantation and platelet-rich plasma (PRP) technology demonstrates a safe and effective therapeutic strategy for the management of long bone fractures in the extremities. This synergistic approach leverages the osteogenic potential and structural support of the autologous periosteum with the concentrated growth factors and enhanced biological healing environment provided by PRP. Clinical evidence indicates that this combination not only promotes robust bone union and accelerates functional recovery but also exhibits a reliable safety profile with minimal complications. Therefore, it represents a satisfactory and promising option for improving outcomes in patients with such fractures.

Disclosure statement

The author declares no conflict of interest.

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