Research Square

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The “Sandwich” Technique for the Treatment of Proximal Humerus Fractures

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Research Article

Keywords: Proximal humerus fracture, Osteoporosis, Locking plate, Bone cement, Medial column support, Reconstruction plate, Sandwich technique

Posted Date: March 8th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-8797001/v1

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Additional Declarations: No competing interests reported.

Abstract

Proximal humerus fractures (PHFs) are common osteoporotic injuries, often complicated by medial column defects and poor bone quality that lead to fixation failure. Conventional methods using lateral locking plates with fibular grafts provide medial support but are limited by donor-site morbidity, immune rejection, and high costs. To address these challenges, we developed a novel “Sandwich” technique—lateral locking plate–intramedullary reconstruction plate with bone cement (LLP-IRPBC)—aimed at enhancing medial and intramedullary support, improving biomechanical stability, and optimizing fixation outcomes in osteoporotic PHFs.

Methods: Five osteoporotic patients (1 male, 4 females; mean age 66.2 ± 8.2 years) with Neer two- to four-part PHFs and medial column defects were treated using the “Sandwich” technique between August 2022 and March 2025. The procedure combined a lateral locking plate, an intramedullary reconstruction plate, bone cement, and cancellous bone grafts to create a three-layer “Sandwich” construct for enhanced support. Postoperative rehabilitation followed a standardized protocol. Functional outcomes were evaluated using the Constant–Murley Score (CMS) and Neer Score at 1, 3, 6, and 12 months.

Results: The mean operative time was 123.0 ± 16.1 min, with an average blood loss of 206.0 ± 85.3 mL, hospital stay of 8.4 ± 1.1 days, and mean hospitalization cost of 56,258.4 ± 6,152.1 CNY. At 12 months postoperatively, all fractures achieved radiographic union without loss of reduction, screw penetration, or varus collapse. The mean CMS was 87.0 ± 6.0 and the mean Neer score was 86.0 ± 6.1. No cases of avascular necrosis or fixation failure were observed.

Conclusion: The “Sandwich” technique provides strong medial and intramedullary support, improves screw fixation, and enhances overall biomechanical stability in osteoporotic proximal humerus fractures. It achieved excellent healing and functional recovery with minimal complications, representing a promising surgical alternative to traditional fibular graft-assisted fixation.

Background

Proximal humerus fractures (PHFs) rank as the third most common type of fracture in osteoporotic patients, with their incidence closely linked to the degree of population aging. As the global elderly population continues to expand, the prevalence of PHFs is expected to increase substantially. In cases where PHFs are accompanied by medial column disruption, the lateral locking plate combined with an intramedullary fibular segment (LLP-IFS) has become the most widely accepted and technically mature approach to enhance medial support. Both autologous and allogeneic fibular grafts have demonstrated satisfactory clinical outcomes, significantly improving the prognosis of patients with varus-type PHFs. However, several limitations remain. In osteoporotic patients, autologous fibular grafts often provide insufficient mechanical strength, and graft harvesting can cause additional trauma and donor-site morbidity. Although allogeneic fibular grafts eliminate donor-site complications, they pose risks of immune rejection, disease transmission, and infection, and their high cost may create a financial burden for patients. Moreover, osteoporotic bone is inherently fragile and prone to comminution after injury[1];

further fragmentation may occur during reduction or fixation, while stress concentration at the bone–implant interface can lead to secondary fractures. Impaired callus mineralization delays healing, and poor cancellous bone quality compromises screw purchase, resulting in implant loosening or pullout[2]. Consequently, osteoporotic fractures are frequently complicated by fixation failure and delayed union due to compromised bone quality[3]. To overcome these challenges, we developed a novel “Sandwich” surgical technique, termed the lateral locking plate–intramedullary reconstruction plate with bone cement (LLP-IRPBC) method, designed to provide enhanced medial and intramedullary support, improve biomechanical stability, and optimize fixation outcomes in osteoporotic PHFs.

Methods

Study Population

This study followed up five patients with proximal humeral fractures (PHFs) who were treated using the “Sandwich” technique at the Second Hospital of Jilin University between August 2022 and March 2025. Among them, there was one male and four females, with ages ranging from 53 to 75 years (mean 66.2 ± 8.2 years). Two cases involved the left shoulder and three the right. According to the Neer classification, there was one two-part fracture, three three-part fractures, and one four-part fracture. All injuries were closed PHFs caused by falls, with no associated shoulder dislocation or rotator cuff injury. Dual-energy X-ray absorptiometry (DXA) showed T-scores of the lumbar spine (L1–L4) and femoral neck ranging from − 2.8 to − 3.8, with an average of − 3.24 ± 0.4 (Table 1). This study was approved by the Ethics Committee of the Second Hospital of Jilin University (approval number: 2024246) and was conducted in accordance with the principles of the Declaration of Helsinki. Informed consent was obtained from all individual participants included in this study.

Table 1
Baseline characteristics of the patients

Male / Female(n)	age(±SD, years)	left/right(n)	Neer classification(Two/Three/Four)	Case	T-score (±SD)
1/4	66.20 ± 8.23	2/3	1/3/1	Fall	-3.24 ± 0.40

Inclusion Criteria for Patients Treated with the “Sandwich” Technique.Patients were eligible for treatment with the “Sandwich” technique if they met all of the following criteria:1.Osteoporosis diagnosed by DXA examination;2.Proximal humerus fracture classified as Neer two-part or more complex fractures;3.Medial column defect present in the proximal humerus fracture;4.No severe pre-existing comorbidities or complications that would preclude surgery or interfere with postoperative shoulder rehabilitation;5.Exclusion of pathological, old (chronic), or open fractures.

Preoperative Preparation and Relevant Examinations

Prior to surgery, the affected upper limb was suspended over the chest using a triangular sling, with the elbow flexed at 90°, to minimize shoulder movement, reduce fracture displacement, and alleviate pain.

All patients underwent routine DXA examination, standard anteroposterior and lateral radiographs of the shoulder, and three-dimensional CT scans of the shoulder joint preoperatively to evaluate fracture severity and displacement (Fig. 2).

Comprehensive preoperative evaluations were performed, including chest CT, electrocardiogram (ECG), complete blood count, coagulation profile, immunological tests, liver and kidney function tests, electrolytes, and blood glucose levels, to rule out any surgical contraindications. The affected upper limb was suspended over the chest using a triangular sling with the elbow flexed at 90° to minimize shoulder movement, reduce fracture displacement, and alleviate pain. All patients underwent routine DXA assessment, standard anteroposterior and lateral shoulder radiographs, and three-dimensional CT scans of the shoulder joint to evaluate fracture severity and displacement (Fig. 2). The surgical procedure, along with potential risks and complications, was thoroughly explained to the patients and their family members, and written informed consent was obtained. Patients were instructed to fast and abstain from drinking for 8 hours before the operation, and prophylactic antibiotics were administered preoperatively.

Surgical Technique

1. All surgeries were performed by a single experienced attending professor. Under general anesthesia, patients were placed in the “beach chair” position, with the affected shoulder elevated and the head turned to the contralateral side to fully expose the operative shoulder. Routine surgical site disinfection was performed, and sterile drapes were applied.
2. Based on the fracture lines, appropriate lengths of the lateral locking plate (90 mm) and reconstruction plate (65 mm) were selected. The two plates were assembled, with the reconstruction plate placed in reverse orientation, shaped, and pre-bent as needed. Locking screws were inserted to determine the optimal height and angle (schematic illustration shown in Figure 3).
3. The surgical approach was through the deltopectoral interval. A curved skin incision was made, and soft tissues were gently bluntly dissected layer by layer to avoid injury to the cephalic vein and the rotator cuff. The deltoid muscle was retracted laterally, and the proximal exposure was extended along the long head of the biceps tendon to reveal the fracture ends. Fracture fragments and intramedullary blood clots and debris were cleared, while preserving viable bone fragments for later use. The assistant applied downward traction and rotation to the patient’s right upper arm to align the intertubercular groove, while the surgeon inserted a periosteal elevator into the proximal humeral shaft and used a levering technique to reduce the fracture.
4. The lateral locking plate was then positioned, with the proximal end 5–8 mm below the tip of the greater tuberosity and the medial edge located 2–4 mm posterior to the intertubercular groove. Kirschner wires (K-wires) were used for temporary fixation of the plate, and fluoroscopy (C-arm) was employed to confirm satisfactory fracture reduction and proper plate placement (Figure 4).

5. The Kirschner wires (K-wires) used for temporary fixation of the lateral locking plate were removed, leaving only the K-wire in the distal ninth screw hole. Before inserting the reconstruction plate into the medullary canal, a 3.5 mm diameter, 10 mm length locking screw was placed into the middle hole of the reconstruction plate to enhance the fixation strength of the bone cement connecting the intramedullary and lateral plates. Under direct visualization, the reconstruction plate was inserted in reverse through the anterior fracture window into the medullary canal, with its depth adjusted according to the relative position of the two plates determined during pre-assembly (schematic, Figure 4A). A K-wire was then slowly inserted through the second distal screw hole of the lateral locking plate, and the depth of the reconstruction plate was fine-tuned with forceps so that the K-wire passed just beneath the reconstruction plate hole (schematic, Figure 4B). Because the screw holes of the reconstruction plate are relatively large, the K-wire engages the plate when lifted, and the locking screw prevents the reconstruction plate from sinking within the medullary canal, effectively linking the two plates and creating a stable platform. K-wires were then sequentially inserted into the remaining screw holes (schematic, Figure 5C). If the intramedullary reconstruction plate obstructed the path of a proximal K-wire, the plate could be slightly adjusted anterior-posteriorly using forceps to allow smooth insertion of the K-wire into the humeral head without compromising the plate's support. Fluoroscopy was used to confirm satisfactory fracture reduction and proper alignment of the reconstruction plate with the lateral locking plate. The K-wires were then sequentially replaced with locking screws, with the tips of the proximal screws positioned within 5 mm of the subchondral bone beneath the humeral head articular surface (Figures 5D and 6). It should be noted that, depending on the fracture pattern, it may not always be possible for two screws to pass simultaneously through both the lateral locking plate and the intramedullary reconstruction plate. In such cases, at least one screw is required to link the plates to prevent sinking of the reconstruction plate within the medullary canal.
6. Under direct visualization, bone grafting was performed in the area of the medial defect using allogeneic cancellous bone. First, a space was reserved between the two plates for bone cement placement. Bone grafts were sequentially implanted into the proximal humeral head, the distal humeral shaft, and the medial fracture region, followed by grafting posterior to the fracture. Next, 5 mL of dough-stage bone cement was introduced through the fracture window to fill the medullary canal between the two plates, thereby fixing the plates and enveloping the screws in the humeral head and on the reconstruction plate. Simultaneously, 20 mL of normal saline was injected with a syringe to locally cool the bone cement, preventing thermal injury to surrounding tissues. Once the bone cement was fully cured, additional bone graft was applied anterior to the cement.

At this stage, bone grafting was completed around the bone cement on all sides—superior, inferior, medial, anterior, and posterior—forming three distinct "Sandwich" structures. The first "Sandwich" structure, oriented from lateral to medial, consisted of the lateral locking plate, bone cement, intramedullary reconstruction plate, and medial bone graft. The second "Sandwich" structure, oriented from top to bottom, consisted of superior bone graft, bone cement, and inferior bone graft. The third

“Sandwich” structure, oriented from anterior to posterior, consisted of anterior bone graft, bone cement, and posterior bone graft (Figure 7).

7) Passive movement of the right shoulder was performed, demonstrating good range of motion, and the internal fixation was stable without loosening. The surgical site was irrigated, hemostasis achieved, and a drain was placed. The subcutaneous tissue and skin were sutured layer by layer, and the incision was covered with a sterile dressing, completing the procedure. Surgical time and intraoperative blood loss were recorded.

Postoperative Management

The right upper limb was supported with a sling for protection. Prophylactic antibiotics were administered for the first three postoperative days to reduce the risk of infection, and the wound was disinfected and dressed every other day. On the second postoperative day, as there was no significant drainage, the surgical drain was removed, and the patient was discharged on the fourth postoperative day. Patients were encouraged to begin early functional exercises to prevent joint stiffness, starting from the wrist and elbow and gradually progressing to shoulder exercises, with the range, frequency, and intensity of movements gradually increased. Within the first four weeks, exercises were primarily passive, including pendulum movements of the shoulder; after four weeks, patients gradually transitioned to non-weight-bearing active exercises, such as shoulder flexion and elevation. Between 6–8 weeks, normal functional exercises were allowed according to the recovery of upper limb function. At 12 weeks, after radiographic confirmation of fracture healing, progressive weight-bearing exercises could be initiated. Patients were advised to maintain adequate nutrition and a balanced diet and to attend regular follow-up visits. Length of hospital stay and hospitalization costs were recorded.

Result

Patients were followed up at 1, 3, 6, and 12 months postoperatively. Standard anteroposterior and lateral radiographs of the shoulder were obtained to evaluate fracture healing, and shoulder joint function was assessed. The Constant-Murley Score (CMS) was used to evaluate pain, activities of daily living (ADL), range of motion (ROM), and muscle strength, with a total score calculated. The Neer scoring system was also applied, recording pain, function, ROM, and anatomical alignment to generate a total score. Poor shoulder functional outcomes were defined as a CMS < 70 points [4]and a Neer score < 70 points at the final follow-up[5].Postoperative complications were also recorded.

The mean operative time for the five patients was 123.00 ± 16.05 minutes, with an average intraoperative blood loss of 206.00 ± 85.32 mL. The mean hospital stay was 8.40 ± 1.14 days, and the mean hospitalization cost was 56,258.40 ± 6,152.10 CNY (Table 2).

Table 2
Surgical data of the patients

Variable	Max	Min	Mean ($\bar{X}$)	SD
Operation time (min)	145	105	123.00	16.05
Intraoperative bleeding (ml)	300	80	206.00	85.32
Hospital stay (days)	10	7	8.40	1.14
Hospitalization cost (CNY)	64173	48054	56258.40	6152.10

The trend of shoulder function recovery over time in the five patients is shown in Fig. 8. At 12 months postoperatively, the mean Constant-Murley Score (CMS) was 87.00 ± 5.96, and the mean Neer score was 86.00 ± 6.12. No cases of poor shoulder functional outcome were observed.

Among the five patients, one had comorbid hypertension and diabetes, one had diabetes and depression, and two had hypertension. One patient with diabetes and depression developed a postoperative incision infection, which healed after regular dressing changes. Another patient with hypertension experienced cerebral infarction 4 months after surgery, presenting with numbness in the left lower limb; symptoms improved after internal medicine treatment without affecting shoulder function or follow-up. All patients achieved satisfactory fracture healing, with no cases of screw penetration, humeral head varus collapse, loss of reduction, or avascular necrosis of the humeral head observed (Fig. 9).

Discussion

Osteoporosis is a systemic skeletal disease characterized by reduced bone mass and deterioration of bone microarchitecture, leading to impaired biomechanical stability of the bone [6]. It primarily affects postmenopausal women but also occurs in elderly men[7]. According to the World Health Organization, a decrease of one standard deviation in bone mineral density increases the relative risk of osteoporotic fractures by approximately 2.6-fold[8]. Epidemiological studies have shown that the incidence of proximal humerus fractures (PHFs) significantly increases among individuals over 50 years of age, particularly in women, and these fractures are mostly the result of low-energy trauma, such as falls from standing height[9–11]. The incidence ratio of PHFs between women and men is approximately 1:1 before the age of 50 but increases to 4:1 after 50 years of age, which may be attributed to factors such as a higher risk of falls in the elderly, unpredictable trauma, increased life expectancy among women, and a greater susceptibility to osteoporosis[12].

With advancing age, the relative bone mass loss in the upper limbs is approximately three times greater than that in the lower limbs, particularly among elderly women[13]. However, cortical bone morphology varies substantially across different anatomical regions. Since the humerus is a non–weight-bearing bone, the proximal humerus is especially prone to rapid bone loss after menopause[14, 15]. The cancellous bone of the humeral head has the highest bone mineral density (BMD) beneath the subchondral cartilage, while the area near the anatomical neck shows decreased BMD—a pattern that

becomes more pronounced in osteoporosis. The site-specific reduction in cancellous bone in osteoporotic patients is most evident in the metaphyseal region, which experiences greater bone loss compared with the humeral head [16]. Compared with the lateral column, the medial column of osteoporotic humeri demonstrates significantly lower BMD. Helfen et al. reported that cortical thinning and increased porosity in the surgical neck of the humerus primarily occur after the age of 65, with marked regional variations in cortical bone among postmenopausal women, especially in the metaphyseal medial column[17]. Compared with the humeral head, greater tuberosity, and lesser tuberosity, the medial column exhibits the most pronounced age-related decline in bone density. Consequently, proximal humeral fractures (PHFs) in osteoporotic patients are often accompanied by medial column bone defects, rendering the region incapable of withstanding compressive forces from the humeral head and leading to postoperative fixation instability and associated complications. Gardner et al. emphasized that mechanical support from the medial column is crucial for maintaining fracture reduction in PHFs treated with locking plate fixation. Both medial comminution and insufficient medial support have been identified as independent risk factors for loss of reduction[18].

The injury mechanism of proximal humeral fractures (PHFs) varies with age and generally presents a bimodal distribution: high-energy trauma is more common in younger individuals, whereas low-energy injuries predominate in the elderly. When evaluating patients with PHFs, surgeons must obtain a thorough medical history and perform a comprehensive physical examination, paying close attention to the patient's overall functional status, such as activity level, hand dominance, and living conditions. It is also essential to assess any previous shoulder trauma or rotator cuff dysfunction in order to determine appropriate treatment options. In elderly patients, PHFs are typically considered fragility fractures, and surgical fixation may be indicated for displaced two-part, three-part, or four-part fractures of the proximal humerus.

We utilized a reconstruction plate instead of a fibular graft to restore medial support, and all patients achieved favorable postoperative outcomes. Previous studies have shown a correlation between screw stability and regional bone mineral density (BMD) in the proximal humerus; Tingart et al. reported a significant relationship between trabecular bone density and screw pullout strength, noting that low BMD often fails to provide adequate anchorage for plates and screws due to shear forces at the bone–implant interface [19]. Building upon these findings, the "Sandwich" technique in this study addresses age-related osteoporotic changes, including reduced trabecular bone density in the humeral head, markedly decreased BMD in the medial column, cortical thinning, increased porosity, and weakened medial support. Bone cement was applied between the two plates to fill the gap and encapsulate the proximal screws, thereby enhancing screw fixation strength. Additionally, cancellous bone granules were used to fill bone defects caused by impaction during reduction; their porous structure provides a larger surface area for vascular and new bone ingrowth, offers strong osteoconductivity, is cost-effective, and can be produced in bulk. After defatting, decellularization, and sterilization, their immunogenicity is significantly reduced and the risk of infection is minimized [20]. Thus, bone grafting in defect areas after internal fixation serves to repair bone loss, promote fracture healing, and reconstruct the medial column.

In the study by Chen et al[21], the use of LLP-IFS for treating elderly patients with PHFs resulted in a mean operative time of 126.00 ± 48.00 min and an intraoperative blood loss of 238.00 ± 83.00 ml. In the present study, the “Sandwich” technique for osteoporotic PHFs achieved a mean operative time of 123.00 ± 16.05 min and an intraoperative blood loss of 206.00 ± 85.32 ml, which is comparable to the results reported by Chen et al. This suggests that, in terms of overall procedural complexity and technical difficulty, LLP-IFS and the “Sandwich” method may not differ substantially, and their perioperative safety profiles are likely similar. It is noteworthy that operative time and blood loss are influenced by multiple factors, including fracture type and severity, the patient’s coagulation function, the surgeon’s skill level, and the coordination of the surgical team, all of which collectively determine the complexity and risk of the procedure.

From the patient’s perspective, one of the most important parameters is the ability to restore quality of life (QoL), as PHFs can affect QoL on multiple levels. Pain and restricted range of motion negatively impact physical functioning and may lead to loss of independence and mobility, which can, in turn, affect social engagement and contribute to emotional and psychological issues in elderly patients, further compromising overall QoL. Therefore, evaluating QoL is clinically important, as it supports patient-centered care and informs treatment decisions. Despite its significance, many studies assessing outcomes of PHFs in elderly patients report markedly reduced postoperative QoL [22]. Commonly used tools for evaluating health-related QoL after PHFs include the Constant-Murley Score (CMS) and the Neer score. The CMS, developed by Pierre Constant and Stuart Murley in 1980, assesses postoperative shoulder function through four components: pain, activities of daily living (ADL), active range of motion (ROM), and muscle strength. It is internationally recognized, precise, and applicable to a variety of shoulder disorders, including fractures, rotator cuff injuries, and arthritis. The Neer score, specifically designed for functional assessment after PHFs, was proposed by Charles S. Neer in 1970 and combines clinical function with imaging results to evaluate pain, functional recovery, ROM, and anatomical reduction quality. It is often used alongside CMS to validate the efficacy of surgical techniques. In the present study, at 12 months postoperatively following the “Sandwich” fixation, the mean CMS and Neer scores were 87.00 ± 5.96 and 86.00 ± 6.12, respectively, demonstrating satisfactory functional outcomes. Comparatively, Lee and Tuerxun et al. reported CMS scores of 87.80 ± 5.60 and 83.70 ± 8.60 in elderly PHF patients treated with LLP-IFS[23, 24]. These results suggest that both fixation methods achieve comparable outcomes in restoring basic shoulder function and daily activities, effectively meeting patients’ functional needs and improving their QoL.

Locking plate fixation is a commonly used surgical method for treating osteoporotic proximal humeral fractures (PHFs), especially for displaced fractures involving two or more parts according to Neer classification. Despite providing good angular stability and anatomical conformity, the complication rate remains relatively high. Screw penetration is the most frequent complication, with an incidence ranging from 0% to 23% [25], and can be categorized as primary or secondary. Primary screw penetration occurs intraoperatively as an iatrogenic injury, for which routine use of three-plane fluoroscopy is recommended to reduce its occurrence. Secondary screw penetration is often caused by osteoporosis, insufficient medial support, or overly long screws; Gardner et al. found that loss of medial support increases the rate

of screw penetration by fivefold [18]. Varus collapse is another common postoperative complication, occurring in 16.3% of cases, often limiting shoulder range of motion, particularly during forward elevation and abduction. Insufficient medial support may contribute to varus collapse, and patients with initial varus displacement have a higher risk of varus malunion postoperatively (40.4%) [9]. Loss of reduction occurs in 4.2%–13.7% of locking plate-treated PHFs and can reach up to 40% in complex fractures, such as Neer three- and four-part fractures [26]. Reduced bone density weakens screw anchorage, and factors such as medial support deficiency, poor reduction, or improper screw placement can disrupt biomechanical balance, accelerating loss of reduction [27]. Subacromial impingement has an incidence of approximately 4.8%, mainly due to malpositioned lateral plates, malunion of the greater tuberosity, or secondary varus collapse of the humeral head[28]. Proper plate positioning and stable medial support are essential to reduce this complication. Full-arc passive shoulder motion before wound closure is critical for assessing impingement. Ricchetti et al. suggested that positioning the plate 15–20 mm below the tip of the greater tuberosity may help prevent impingement [29]. Avascular necrosis of the humeral head is the most severe complication following locking plate fixation, with an incidence of 4.4%–10.8% [30]. Impaired blood supply is the primary cause, and the integrity of the medial soft tissue, the length of the posteromedial metaphyseal column, and fracture type are key predictors of humeral head avascular necrosis. Fjalestad et al. noted that in displaced three- and four-part PHFs, the incidence of humeral head avascular necrosis is higher with nonoperative treatment compared to surgical fixation [31].

Multiple studies have confirmed that augmenting medial support can significantly reduce the incidence of complications. Nie et al. reported a complication rate of 21.8% for PHFs treated with locking plates alone, compared with 8.9% for those treated with LLP-IFS [32]. Similarly, Cui et al. found complication rates of 28.57% and 12.0% for locking plate fixation alone versus LLP-IFS, respectively [33]. In the present study, all five PHF patients treated with the “Sandwich” technique achieved satisfactory fracture healing and significant improvement in shoulder function, with no related complications observed. The clinical efficacy was clear and satisfactory; however, further studies with larger sample sizes are needed to evaluate the long-term outcomes and safety of the “Sandwich” method.

The clinical application of the “Sandwich” technique demonstrates its effectiveness in treating osteoporotic PHFs and provides a clear direction for clinical management. The reconstruction plate provides direct load-bearing support beneath the humeral head articular surface while also supporting the medial column, enhancing biomechanical stability after fracture fixation. Augmentation with bone cement effectively prevents screw loosening and implant failure, and adequate bone grafting promotes fracture healing and medial column reconstruction. Following proper fracture healing and shoulder function recovery, the final surgical outcomes were satisfactory, with no postoperative complications, including screw penetration, implant loosening, varus displacement, or humeral head avascular necrosis. Compared with autologous or allogeneic fibular grafts, the “Sandwich” technique offers several advantages: first, it provides robust biomechanical stability, ensuring strong medial support and significantly reducing micro-movement and subsequent bone resorption; second, it markedly enhances screw fixation strength, effectively preventing screw loosening and implant failure; third, it reduces the

risk of infection or disease transmission; fourth, intramedullary placement of the reconstruction plate with medial cortical bone grafting facilitates the restoration of normal medial column morphology after fracture healing; fifth, the overall structural stability allows for early functional exercises, minimizing muscle atrophy, tissue adhesion, and restricted mobility. Adequate bone grafting at the fracture site further promotes healing and recovery, reducing the incidence of postoperative complications and the need for revision surgery.

In conclusion, the “Sandwich” technique is suitable for two-part, three-part, and four-part proximal humeral fractures with displacement of the humeral head or greater tuberosity. For minimally displaced fractures (< 1 cm), conservative treatment remains the first choice. In cases of severely comminuted proximal humeral fractures, humeral head split fractures, fracture-dislocations, high risk of internal fixation failure, or an elevated likelihood of humeral head necrosis, shoulder arthroplasty should be considered. Given the presence of comorbidities, revision surgery is often not feasible for many elderly patients; therefore, surgeons must carefully evaluate all relevant factors and tailor the surgical plan to each patient’s individual needs.

Limitations

The “Sandwich” fixation technique proposed in this study provides a novel approach for the treatment of proximal humeral fractures, but it still has certain limitations. First, although the biomechanical stability of this method is theoretically superior to that of single plating or cement augmentation alone, large-scale prospective clinical studies are lacking, and its long-term outcomes have not been fully validated. Second, the use of bone cement around the joint carries potential risks, including thermal injury, cement leakage, and impacts on local blood supply, which require particular caution in elderly osteoporotic patients. Third, the “Sandwich” fixation procedure is relatively complex, demanding high surgical skill, and the increased number of implants may expand the range of soft tissue dissection, thereby increasing the risk of infection and compromised blood supply. Finally, this study did not fully evaluate the applicability of this technique across different fracture types and age groups; multicenter randomized controlled trials are still needed to confirm its safety and clinical advantages.

Conclusion

The "Sandwich" technique represents a promising surgical option for treating osteoporotic proximal humeral fractures (PHFs). Postoperatively, patients achieved satisfactory fracture healing and significant improvement in shoulder function, with no observed complications such as varus collapse, loss of reduction, or avascular necrosis of the humeral head, resulting in overall favorable clinical outcomes.

Declarations

Author contributions

WYQ and LY investigated and summarized the literature and wrote the original draft. ZZY and SXD conducted deep review and editing. WSJ conducted deep review. PCD helped revise the paper, supervised the paper. All authors have read and approved this manuscript for publication.

Funding

None

Acknowledgements

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest:

The authors declare that they have no conflict of interest.

Ethical approval:

This study was approved by the Ethics Committee of the Second Hospital of Jilin University (approval number: 2024246) and was conducted in accordance with the principles of the Declaration of Helsinki. Informed consent was obtained from all individual participants included in this study.

Clinical trial number:

Not applicable.

Consent for publication

Not applicable.

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Figures



Figure 1

Figure 2. X-ray of the right proximal humerus fracture in a patient

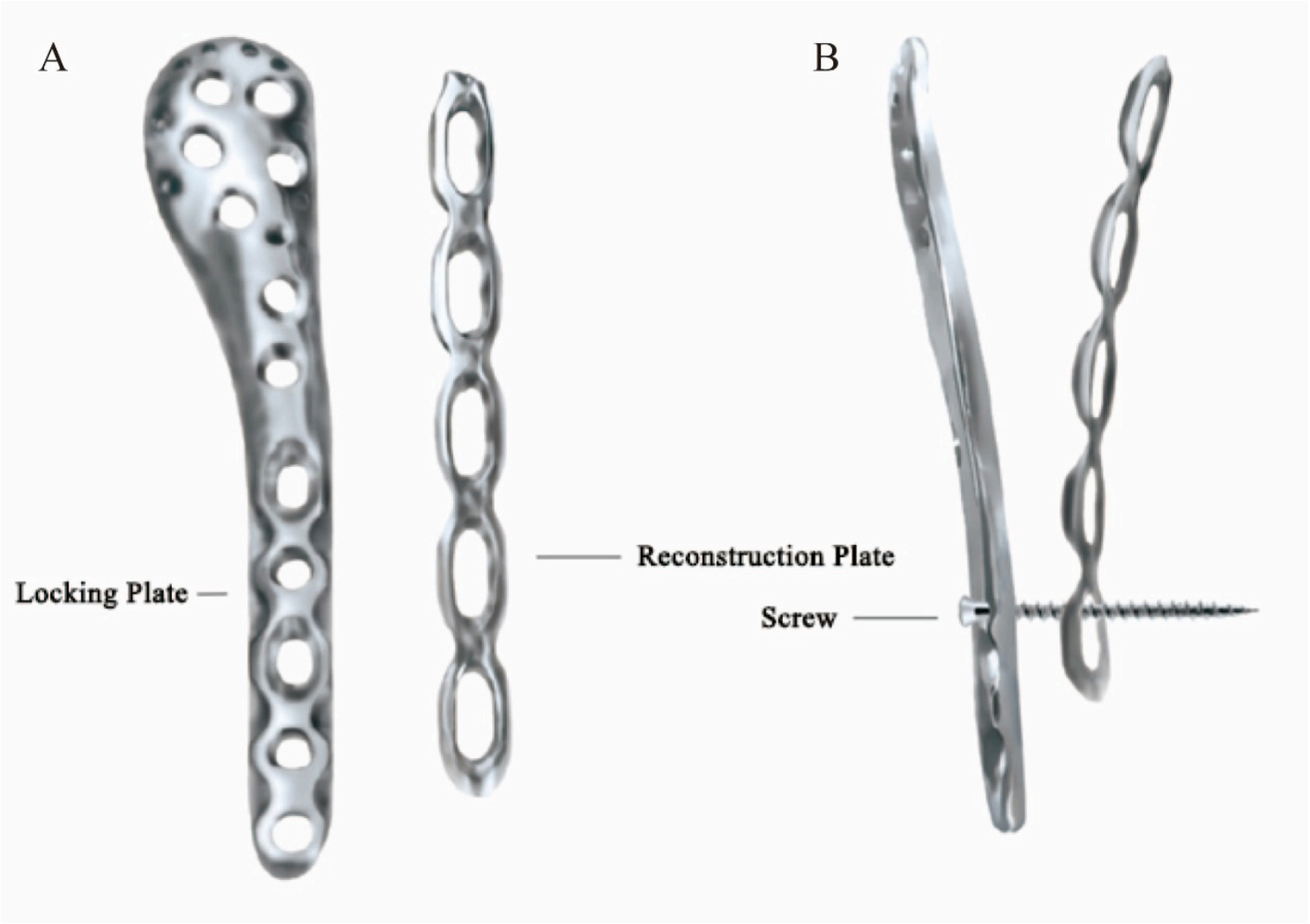


Figure 2

Figure 3. A.Selection of appropriately sized plates: a lateral locking plate (90 mm) and a reconstruction plate (65 mm); B. Assembly of the two plates, with the reconstruction plate shaped and pre-bent as needed.

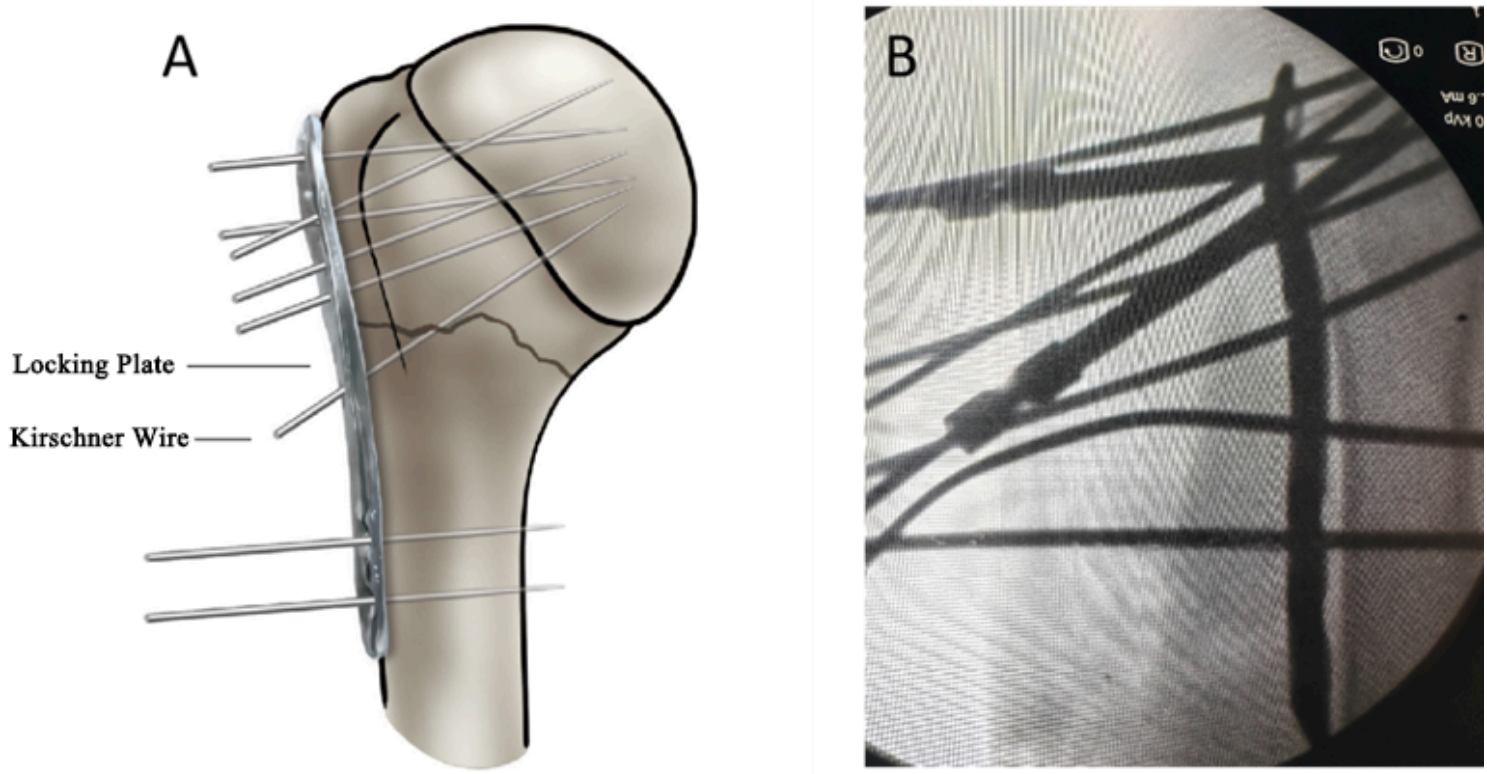


Figure 3

Figure 4. A. Schematic illustration; B. Intraoperative X-ray

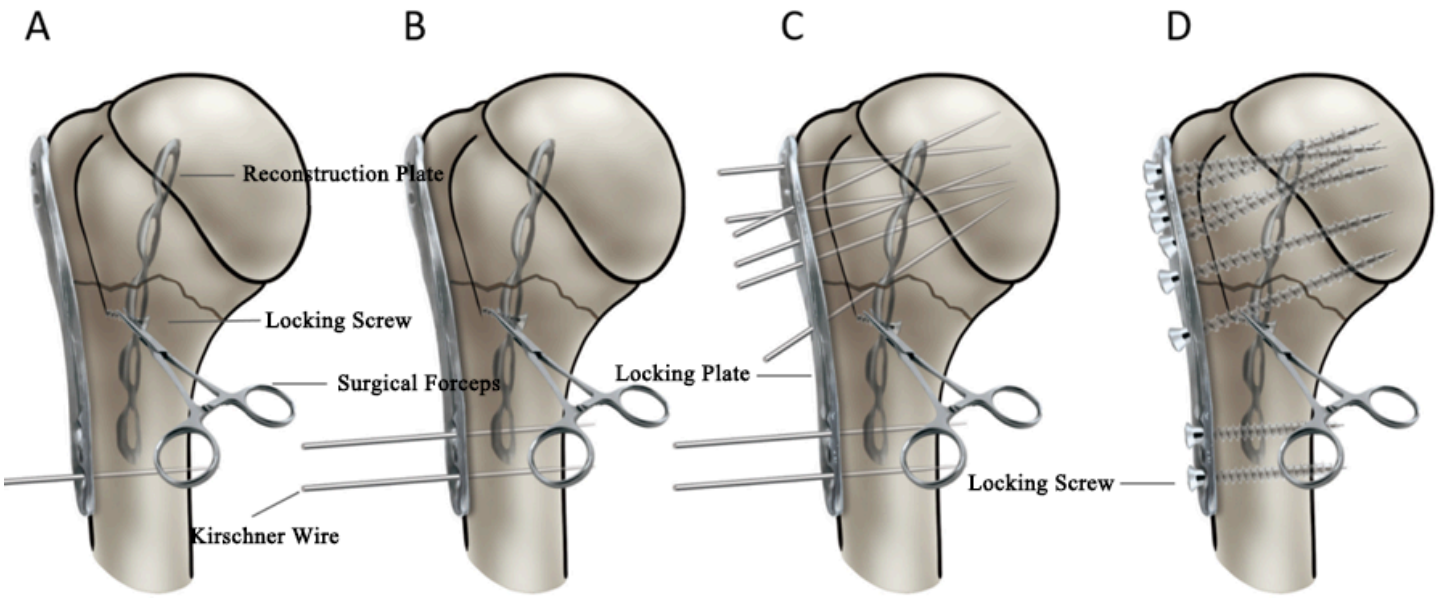


Figure 4

Figure 5.A. After inserting an inverted short screw into the middle hole of the reconstruction plate, it is introduced retrogradely into the medullary canal through the anterior fracture window; B. A Kirschner wire is inserted through the second distal hole of the lateral locking plate so that it passes precisely through the most distal hole of the intramedullary reconstruction plate; C. Kirschner wires are sequentially inserted into the remaining screw holes; D. The Kirschner wires are then replaced with locking screws.



Figure 5

Figure 6. Intraoperative X-ray

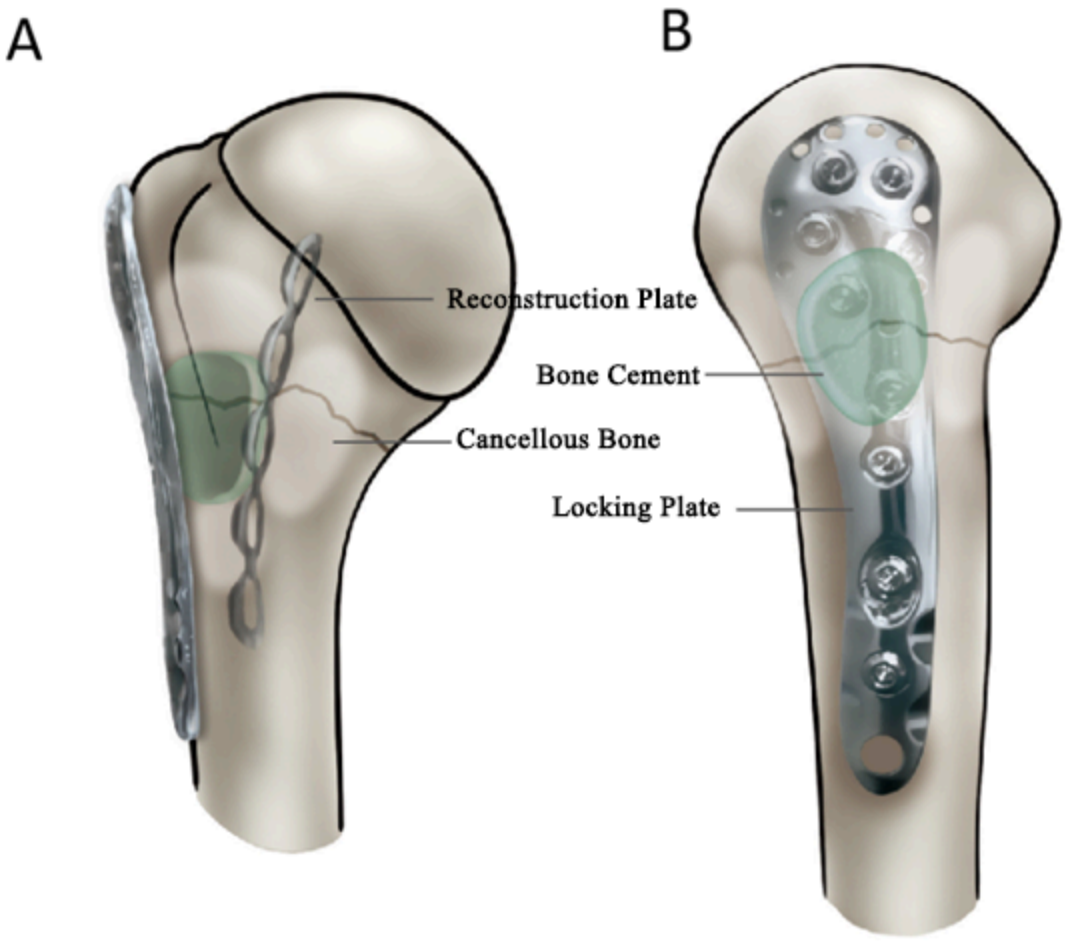


Figure 6

Figure 7. A. Anteroposterior view; B. Lateral view (green represents bone cement, white represents allogeneic cancellous bone).

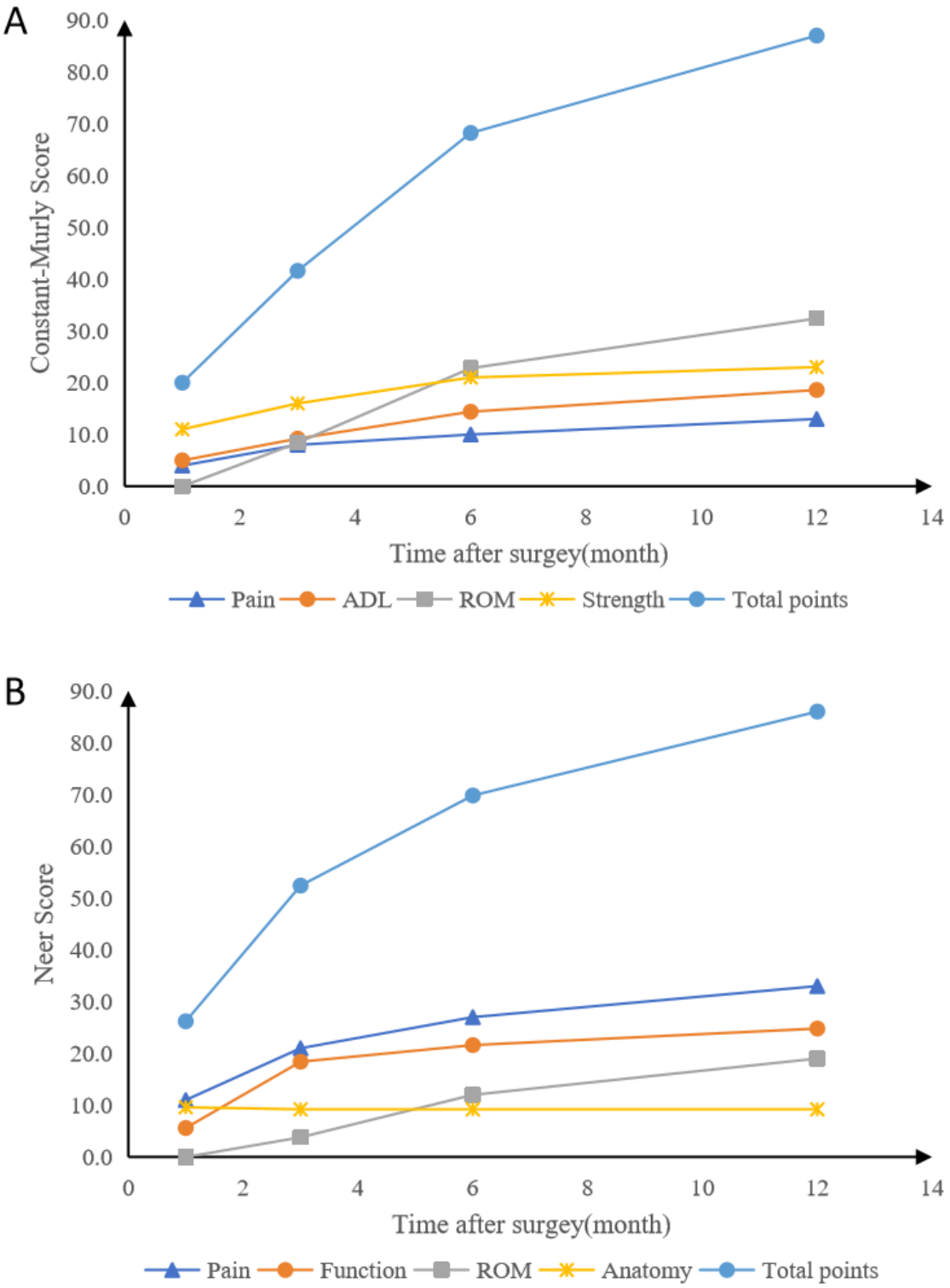


Figure 7

Figure 8. Constant-Murley Score; B. Neer Score

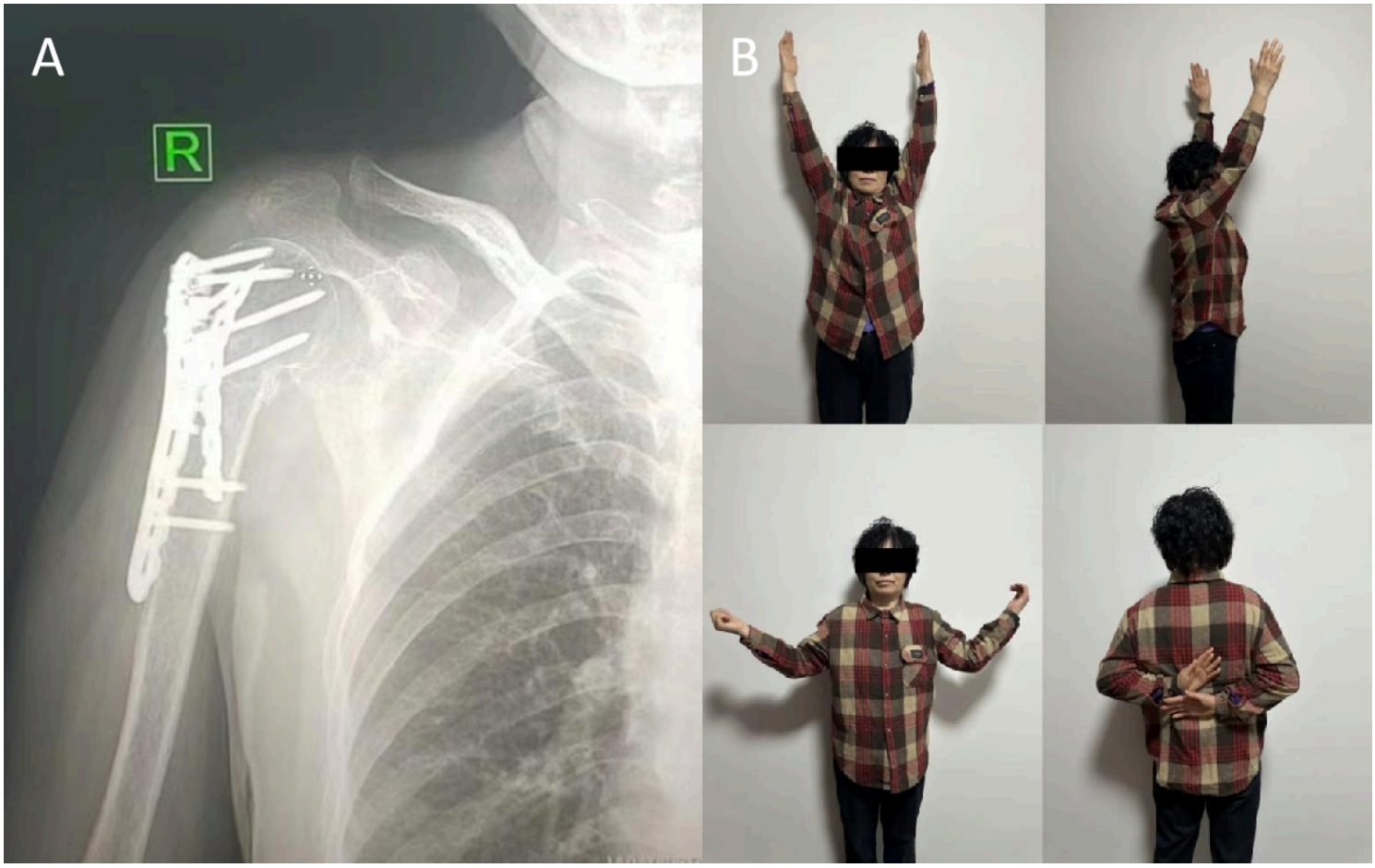


Figure 8

Figure 9. A. X-ray at 6 months postoperatively; B. Shoulder function at 12 months postoperatively (abduction, forward flexion, external rotation, and internal rotation).