

Original Research Article

A novel technique to treat osteoporotic proximal humeral fractures with diaphyseal extension

Ahmed Fouad Abotaleb*

Faculty of Medicine, Alexandria University, Egypt

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*Correspondence:

Dr. Ahmed Fouad Abotaleb,

E-mail: Ahmed.abotaleb.clinic@gmail.com

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ABSTRACT

Background: Recent reports of failure of proximal humeral locked plate (PHILOS) in treating comminuted proximal humeral fractures (PHF) with diaphyseal extension (DE) prompted attempts to either augment or add more fixation which is challenged with the proximity to important neurovascular structures.

Methods: Between February 2020 and May 2024, 29 patients with comminuted fractures of PHF-DE were treated at El-Hadra University Hospital with the addition of either a small locked dynamic compression plate (sLDCP) or a small locked reconstruction plate (sLRP) to the standard PHILOS plate, using the trans-deltoid approach.

Results: The average follow-up (FU) period was about 19.5 months. The average age of the patients was approximately 62.6 years. Most of the patients (72.4%) were females. All patients healed their bones without needing additional procedures like bone grafts. The average healing time was just over six months. The mean visual analogue scoring system (VAS) was 8.2. At the end of the FU, there was no significant change in the neck shaft angle ($p=0.7$). At the end of the FU, the average Constant-Murley shoulder score was noted as 86.6, the mean Simple Shoulder Score was 79.3%, and the average score for the shoulder rating at the University of California Los Angeles (UCLA) was 31.1. No iatrogenic neurovascular fractures occurred during the study.

Conclusions: Performing double plating on PHF-DE is safe. It does not increase the risk of shoulder impingement, harm to the blood supply of the humeral head, or nerve injuries caused by treatment.

Keywords: Osteoporotic fractures, Proximal humeral fractures, Comminuted fractures, Diaphyseal extension, Double plating, Double plating proximal humerus, Dual plating

INTRODUCTION

Proximal humerus fractures (PHFs), affecting a large number of older adults (over 250 per 100,000 people older than 65), are often linked to weakened bones (osteoporosis) and severe trauma. These fractures are more prevalent in females, and complex fractures involving multiple fragments are on the rise. PHFs can result in significant health problems, increased mortality, and substantial healthcare costs.^{1,2}

The management of PHF ranges from conservative (non-surgical) methods to surgical procedures like open

reduction and internal fixation (ORIF), partial shoulder replacement, or reverse total shoulder replacement (RTSA), with the optimal treatment approach still under investigation. Surgical intervention, frequently employing locking plates and screws, is a common strategy for addressing PHFs. However, elderly individuals undergoing PHILOS fixation are at a higher risk of complications, particularly in the presence of osteoporosis. The most commonly observed issues include avascular necrosis (bone death due to insufficient blood supply), screw penetration, and loss of fracture alignment.^{3,4}

The selected treatment approach typically depends on the patient's general health, the fracture characteristics,

available resources, and the surgeon's experience. PHF-DE often involve damage to the medial calcar, a critical structure for maintaining fracture stability and preventing collapse into a varus deformity, which can limit function.^{5,6}

Highly fragmented PHF can lead to lasting impairment and ongoing functional limitations if they don't mend properly, considering the patient's activity level and the shoulder's ability to compensate for any issues.⁷ The calcar is particularly vital for ensuring stability after surgery.^{8,9}

Various adjustments to the PHILOS plate have been developed to reduce the risk of surgical failure. Some researchers initially believed that placing screws only in the lower inner area of the humeral head, specifically targeting the calcar, would prevent collapse.¹⁰ However, later studies showed a significant failure rate even when bone grafts were added.¹¹ Other researchers suggested using more screws to improve stability. Anchors were also described to help realign and secure the tuberosities along with the plate.^{12,13} When a single plate on the side wasn't strong enough for very fragmented fractures, the double plating technique was created, involving adding another plate to the front, back, or inside of the bone.^{14,15}

The aim of bone grafting is to strengthen the inside support of the fracture. Bone from the patient or a donor can be used to fill gaps in the bone near the joint. Early reports showed positive results using spongy bone and fibular struts from donors. As another option, cement was introduced. These are injectable synthetic materials that harden inside the body, such as polymethylmethacrylate or calcium phosphate.¹⁶

Various double plating techniques for the proximal humerus have been documented. Most reported methods involve using an additional small plate over the lesser trochanter, a specialized medial plate, or a locked plate typically used for wrist fractures.¹⁷⁻²⁰ Some reports even describe using two small plates.^{21,22}

The aim of this study was to evaluate the safety as well as the effectiveness of applying a second plate to the standard PHILOS plate and assess whether the morbidity of the procedure is increased or any of the complications happened more than what is reported in the literature and whether there is an actual benefit of applying the second plate in these complex fractures.

METHODS

This study reports on the results of treating 29 patients with PHF-DE in a prospective study. These patients were treated at El-Hadra University Hospital in Egypt between February 2020 and May 2024.

Patients were included in the study sequentially after exclusion of those with open wounds, fractures caused by disease, those under 18, those with pre-existing nerve weakness in the arm, those with multiple injuries, cases of

delayed or non-healing fractures, shoulder dislocations, and those who didn't complete at least a year of follow-up care after surgery.

Initially, 35 patients were treated with this surgical method, but six were excluded: three died from causes unrelated to the surgery, and three stopped attending follow-up appointments after nine months. All patients agreed to the treatment after understanding the available options and their potential risks and benefits.

Each patient underwent thorough medical assessments. X-rays were initially taken, and CT scans were sometimes ordered. A sling was used for initial support. Surgery was scheduled as soon as possible after the patient's overall health was optimized, including addressing factors like anaemia with blood transfusions.

Before surgery, patients received a single dose of intravenous antibiotics, selected based on local guidelines for common surgical site infections, at least 30 minutes before the incision.

During surgery, patients were positioned at a slight incline (15-20 degrees anti-Trendelenburg) with radiolucent arm support to allow the surgeon to clearly see the entire proximal humerus with the C-arm fluoroscope. Initial images were taken with the C-arm.

The surgical area was prepared with drapes and antiseptic. An adhesive drape (Opsite) was applied. A trans-deltoid approach was used, taking care to protect the axillary nerve by limiting the deltoid muscle splitting to 2 inches above and 4 inches below acromion. Sutures were placed in the rotator cuff tendons to help reduce them and were attached to PHILOS plate at the end of the fixation. Rotator interval was then accessed with external rotation of shoulder, aiding in reduction of intra-articular fracture lines.

When inserting the plate under the muscle, the shoulder was moved away from the body (abducted) to protect the axillary nerve and the posterior circumflex humeral artery from the humerus. The PHILOS plate was initially secured with K-wires at the top and bottom. Imaging was used to confirm correct placement of plate and fracture reduction.

First, two non-locking screws were inserted through the plate to check how well the plate contacted the bone. Then, the remaining screws were inserted in sequence. A second plate, either sLDCP or sLRP, was selected and positioned between the PHILOS plate and the pectoralis major tendon. The upper part of this plate was carefully shaped to fit the bone. A K-wire was initially placed through a hole in the second plate near the joint, then a distal non-locking screw was added to ensure the plate sat firmly against the bone. Next, two locking screws were placed in the upper portion of the plate, positioned differently from the PHILOS plate screws to help stabilize any head split fractures. The lower screws of the second plate were carefully placed to avoid overlapping the screws from the

PHILOS plate, preventing areas of concentrated stress that could weaken the bone.

Final imaging was performed before closing the wound, which was stitched in layers. Bleeding was controlled before closing. A drain was not needed in any of the cases.

Postoperative treatment

Following the operation, patients received antibiotics for the first 48 hours to minimize the risk of infection. Analgesics were administered according to the patient's comfort level, and anticoagulants were used for a fortnight to reduce the risk of thrombosis. Radiographs were performed immediately post-op and during subsequent check-ups. These radiographs included two perpendicular

projections. The femoral neck angle was measured on the initial anterior projection and again on the final anterior projection during follow-up.

All patients were encouraged to start active-assisted forward flexion and pendulum exercises as tolerated. A sling was worn between exercise sessions to promote healing. Each patient had a tailored rehabilitation plan supervised by a physical therapist. Fracture union was determined radiographically by the presence of a bony callus across the fracture site and confirmed via physical examination (Figures 2 and 3).

Treatment was considered unsuccessful if a patient required revision surgery to promote fracture healing or underwent total joint arthroplasty.

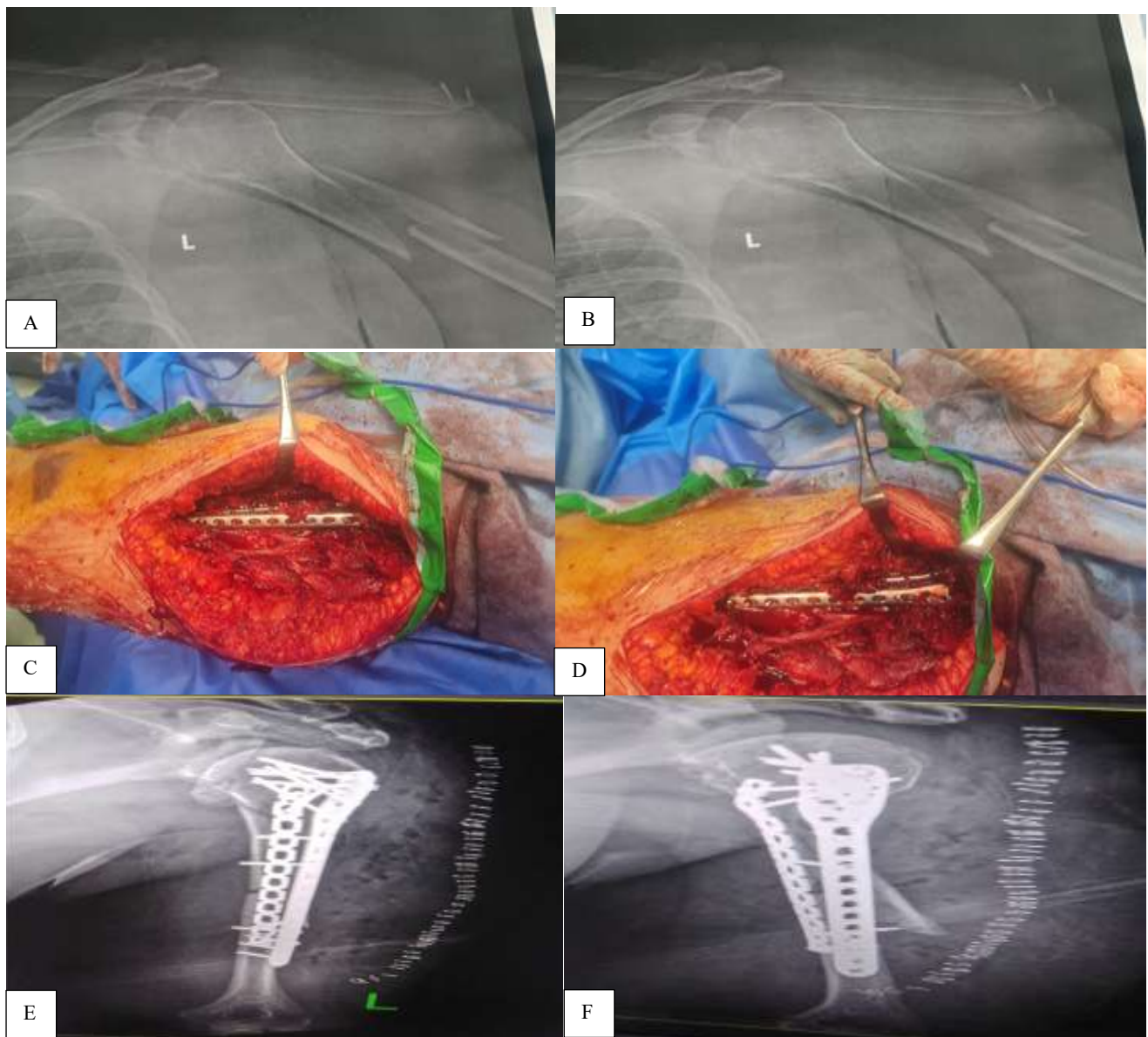


Figure 1 (A-F): A and B-preoperative x-ray of 66 years old female who sustained fall downstairs, C-an intraoperative photo showing the relationship between 2 plates across shaft, D-intraoperative photo showing proximal position of the 2 plates with the axillary nerve passing over the proximal part of the PHILOS plate and the tendon of the pectoralis major i. e.; the lateral lip of the bicipital groove, E and F-are the postop x-rays.

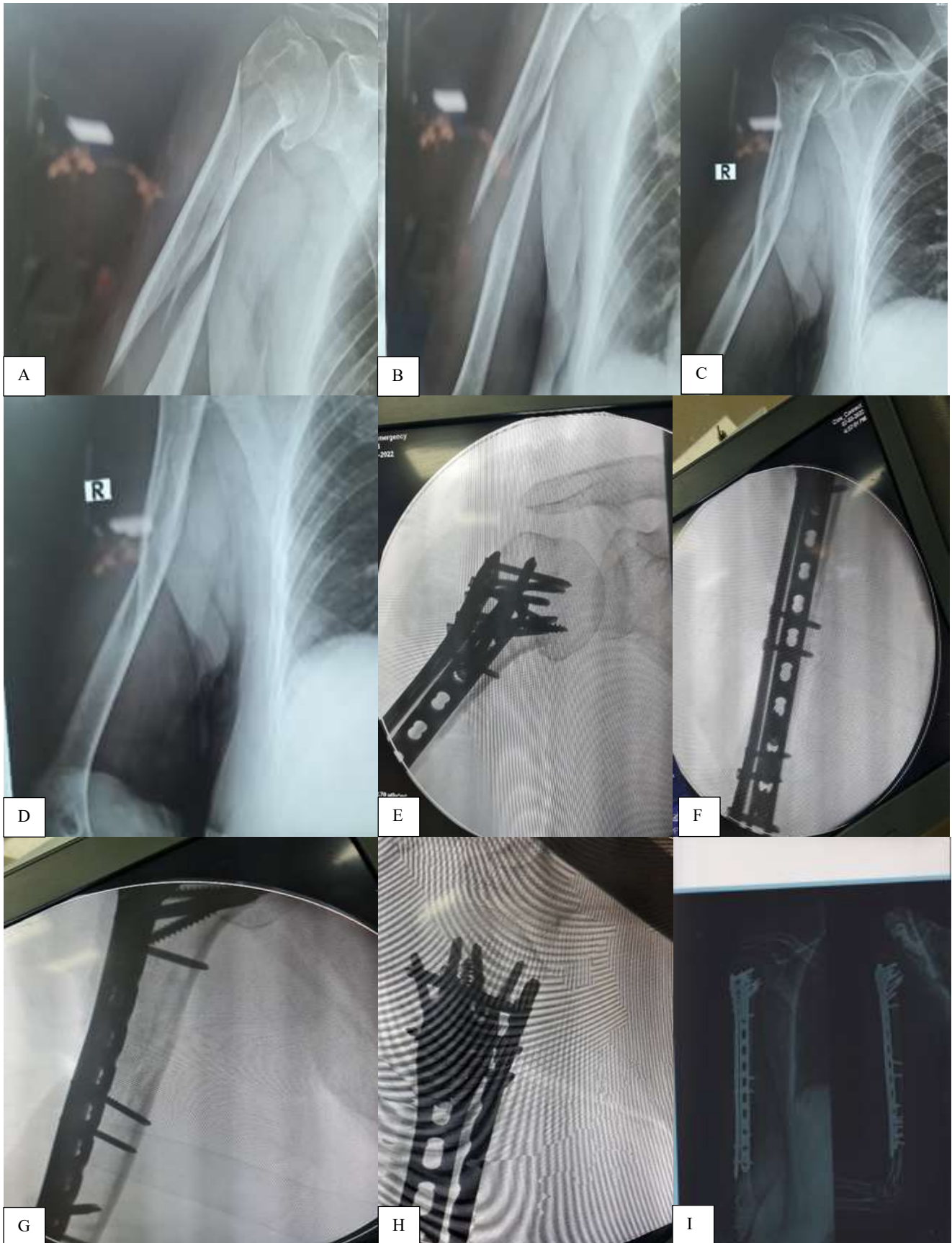


Figure 2 (A-I): 61 years old female was a victim of a road traffic accident as a pedestrian, A-D are the preoperative x-rays, E-H is the intraoperative image intensifier photos after fixing the fracture with the 2 plates, I-am the final x-rays at the final follow up, the fracture achieved union in 6 and half months.



Figure 3 (A-E): 64 years female who sustained a fall downstairs, A and B are the preoperative x-rays, C- are the preoperative reconstructed CT images, D and E are the postoperative x-rays

Statistical analysis

Numerical data were summarized using descriptive statistics, including means, standard deviations, and minimum/maximum values. The Shapiro-Wilk test assessed normality. Normally distributed data were compared using independent samples t-tests. The non-parametric Mann-Whitney U test was employed for non-normally distributed data. Statistical significance was defined as a p value less than 0.05. IBM SPSS statistics version 26 (Chicago, IL) was used for all analyses.

Ethical approval

Appropriate ethical approval was obtained from the ethical committee of medical ethics of the faculty of medicine-Alexandria university (IBR number: 00012095, FWA number:00018699).

RESULTS

The average duration of the follow-up was 19.5 months $\pm$ 3.3 (range, 12-26 months). The average age was 62.6 years $\pm$ 7.6 (from 41 to 78 years). Table 1 summarises demographic numeric data. There were 8 male patients (27.6%) and 21 female patients (72.4%), (Figure 4). Seventeen patients (58.6%) had the fracture in their dominant limb, while 12 patients (41.4%) experienced it in their non-dominant limb (Figure 5).

Table 1: Summary of demographic numeric data.

Variables	Mean	SD
Age (in years)	62.6	7.6
Time between injury and surgical fixation (Days)	5.9	1.7
Duration of surgery (Minutes)	144	19
Number of unites of packed RBC transfused perioperatively	1.6	0.7
Duration till healing (Months)	6.1	1.5
Duration of follow-up (Months)	19.5	3.3

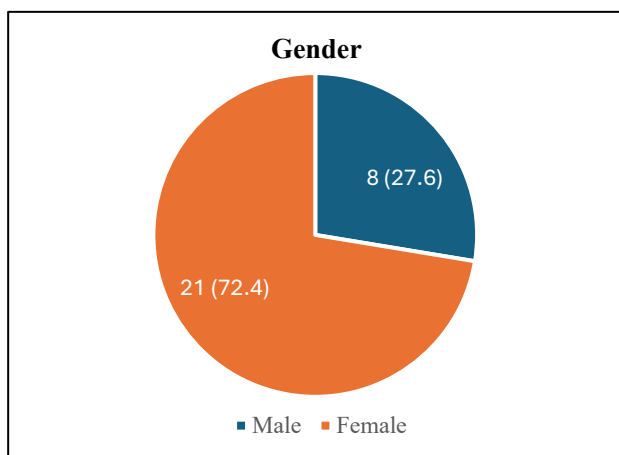


Figure 4: Gender distribution of the study participants.

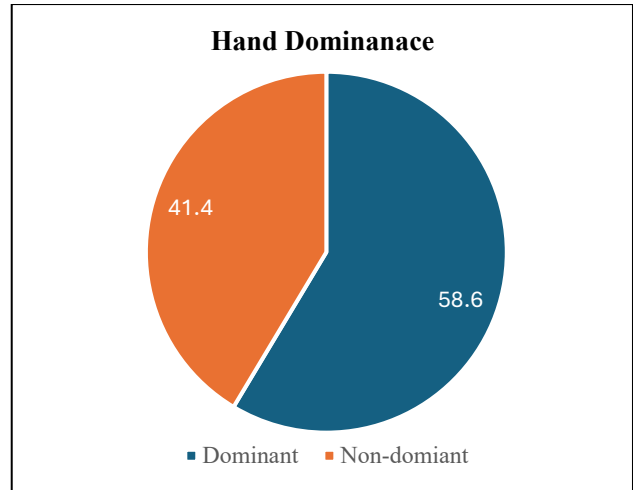


Figure 5: The distribution of hand dominance in the study participants.

Just six patients, or 20.7%, had no other health problems. Twelve patients, or 41.4%, had only high blood pressure. Two patients, or 6.9%, had only type 2 diabetes. Six patients, or 20.7%, had both hypertension and type 2 diabetes. Three patients, or 10.3%, had hypertension along with ischemic heart disease (Figure 6).

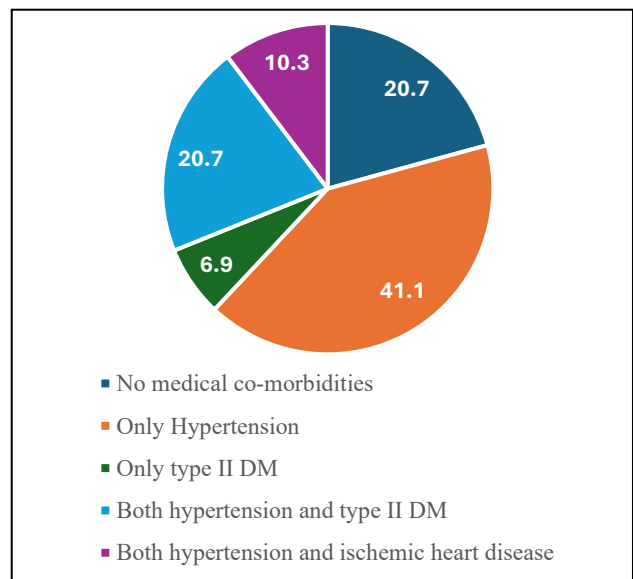


Figure 6: The distribution of medical co-morbidity in the study participants.

The average time between injury and the surgical fixation was about 5.9 days, ranging from 3 to 11 days. The typical duration of the surgery was approximately 144 minutes, with times varying from 110 to 180 minutes. In 10 patients, or about 43.5%, the second plate used was a sLDCP. The remaining 19 patients, or 65.5%, received a sLRP as their second plate (Figure 7). On average, patients received 1.6 units of packed red blood cells during transfusion, with some receiving as few as 1 unit and others up to 3 units. The standard deviation for transfused units was 0.7.

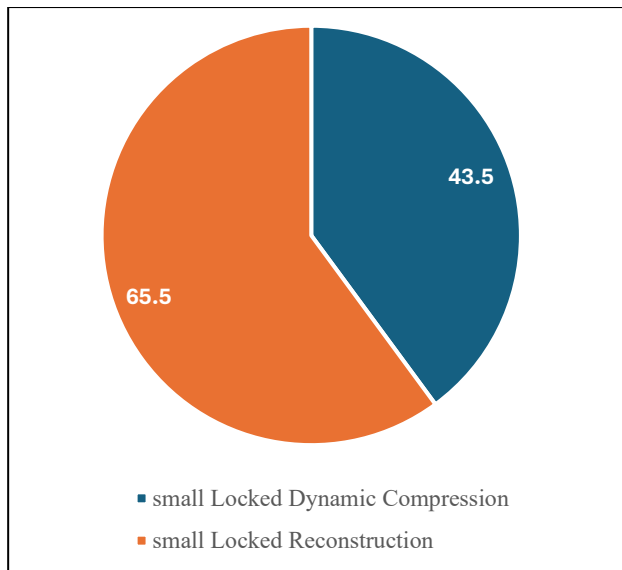


Figure 7: The distribution of the second plate in the study participants.

Every patient experienced bone healing without needing additional procedures like bone grafting. The average time for the bones to heal was just over six months, ranging from four to nine and a half months. The standard deviation was about one and a half months.

One patient with preoperative radial nerve palsy recovered completely in 6.5 months. Two patients experienced palsy of the axillary nerve after surgery. During fixation, the nerve was checked through the trans-deltoid approach and appeared fully intact. These patients recovered in 2 and 2.5 months, respectively. No other patients showed nerve problems before or after surgery. There were no signs of superficial or deep infections at the surgical site. No patients developed avascular necrosis (AVN) of the humeral head after surgery. None needed joint replacement or removal of metalwork.

Table 2: Summary of the range of motion in degrees achieved at the end of the follow-up.

Variables	Mean	SD
Forward flexion	165.4	7.6
Extension	37.3	3.6
Adduction	39	4.5
Abduction	166.3	7.2
External rotation	44.3	7.5
Internal rotation	68.3	6.3

By the conclusion of the follow-up period, the mean forward flexion was recorded at 165.4 degrees, with values spanning from 150 to 177 degrees and a standard deviation of 7.6. The mean extension measured 37.3 degrees, with a range of 29 to 42 degrees and a standard deviation of 3.6. For adduction, the average was 39 degrees, with a range of 30 to 45 degrees and a standard deviation of 4.5. Abduction had an average of 166.3 degrees, with a range from 150 to

175 degrees and a standard deviation of 7.2. The mean external rotation was 44.3 degrees, with a range between 35 and 65 degrees and a standard deviation of 7.5. Internal rotation averaged 68.3 degrees, with values ranging from 50 to 75 degrees and a standard deviation of 6.3 (Table 2).

On the VAS, patients reported an average subjective satisfaction score of 8.2, with scores ranging from 6 to 10 and a standard deviation of 1.3. In this system, 0 indicates the lowest satisfaction level, while 10 signifies the highest. By the conclusion of the follow-up period, the average neck-shaft angle was measured at $129.3^{\circ} \pm 3.9^{\circ}$ (range: 123° - 138°), compared to $129.4^{\circ} \pm 4.2^{\circ}$ (range: 123° - 140°) immediately after surgery. The difference in neck-shaft angles between the post-operative period and follow-up was not statistically significant ($p=0.7$).

Upon conclusion of the follow-up, the mean Constant-Murley shoulder score was recorded at 86.6, with a range from 65 to 96 and a standard deviation of 8.8. Out of the patients, 23 individuals (79.3%) achieved excellent outcomes, scoring over 86 points. Additionally, 3 patients (10.3%) attained good results, with scores between 71 and 85 points, while another 3 patients (10.3%) had fair outcomes, scoring between 56 and 70 points, figure 8. The average Simple Shoulder Score was 79.3% with a standard deviation of 9.8%, ranging from 50% to 92%. The mean score for the UCLA shoulder rating was 31.1, with scores ranging from 24 to 34 and a standard deviation of 2.5.

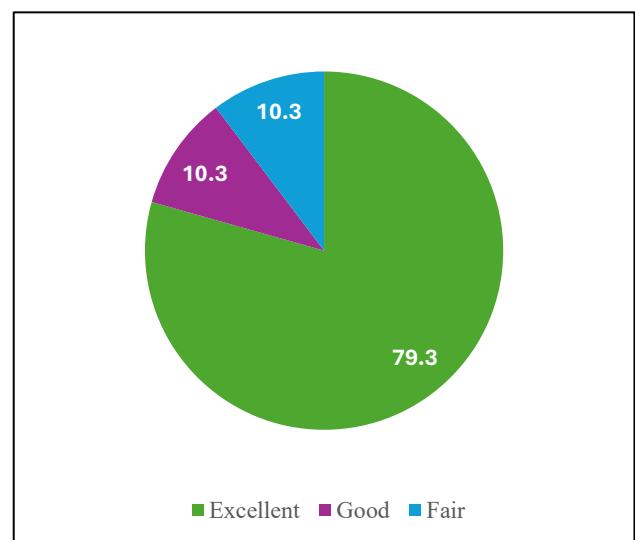


Figure 8: The distribution of the cases according to the Constant-Murley shoulder score at the end of the follow-up.

DISCUSSION

Despite earlier reports that PHF can be sufficiently fixed with 2 plates of the 1/3 tubular design.²² A later study confirmed the superiority of a single locking plate over the two 1/3 tubular plates.²³ 1/3 tubular plates was not used as the second plate in any patient in the current study.

AVN humeral head occurred in a patient in a study which involve only seven patients in which a 1/3 tubular plate over the bicipital groove was used in addition to the PHILOS plate.²⁰ In the event of significant trauma, the ascending branch of the posterior circumflex humeral artery, which is identified as the primary source of blood supply to the humeral head, is possibly damaged, which leads to a heavy burden over the ascending branch of the anterior circumflex humeral artery to sustain blood supply to the humeral head. Endangering this vessel by violating the bicipital groove would increase the odds of developing AVN. In the current research, AVN didn't develop in any case during the follow-up duration.

Humeral head's AVN was also reported as a complication of double plating in a study in which the bicipital groove harbouring the anterior circumflex artery contribution to the blood supply of the humeral head is violated.²⁴ while in the current study which didn't violate the bicipital groove, no single case of humeral head AVN was observed during the period of the follow-up.

A significantly lower biomechanical performance of PHILOS plate only in comparison to PHIOLS pate with fibular strut graft (which behaved fairly), and addition to of another locking plate whether a medial locking plate or a nearby distal radius locked plate (both of them behaved in an excellent fashion) in both normal and osteoporotic cadaveric models.¹⁸ Practically the addition of a medial column plate would carry an enormous risk to the vital neurovascular structures and the distal redial locked plate have a bulky metaphyseal part which will necessitate aggressive stripping of the soft tissues around the head. The current study offers a novel solution to have 2 locking plates without excessive soft tissue stripping or endangering the vital neurovascular structures.

In the current research, a mixture of locking and non-locking screws was employed to ensure limitation of impingement against the surrounding soft tissues while maintaining the blood supply of the fractured fragments as shown in multiple studies.²⁵

An analysis of the data from 2010 to 2018 from the federal association of local health insurance funds in Germany of patients older than 65 years old suffering from PHF revealed an increasing trend towards either augmenting or adding fixation to PHILOS plate rather than using it alone, however the numbers of double plating are still small, which can be explained by the difficulty of this technique and preference of arthroplasty as a definitive option in such difficult cases. The most commonly used approach for double plating in this cohort was the delto-pectoral approach.⁷ In the current study, the use of the trans-deltoid approach facilitated the application of the 2 plates without impinging on the surrounding soft tissue sleeve.

Minimising the stress riser effect from the 2 plates by ensuring that the screws from the 2 plates ended at a

different level was supported by earlier studies.²⁶ None of the cases experienced peri-implant fracture in this study.

A variable angle locking distal radius plate was applied through extensive posterior dissection together with PHILOS plate in a cohort of 21 cases, which experienced a case of AVN and a case of impingement.¹⁹ In the current study no extensive dissection was used, neither AVN or impingement happened in any of the cases.

The limitations of the study are lack of a control group, and small number of patients.

CONCLUSION

Hereby, the presented technique is safe and effective and can allow early mobilisation in such difficult fractures and osteoporotic patients without the risk of implant failure and it presents a significant advantage over other reported techniques in the literature.

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Conflict of interest: None declared

Ethical approval: The study was approved by the Institutional Ethics Committee

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