

# Functional results of double plating for comminuted fractures of the proximal humerus

## Ahmed Fouad Abotaleb

Department of Trauma and Orthopedics, Faculty of Medicine, Alexandria University, Alexandria, Egypt

Correspondence to Ahmed Fouad Abotaleb, MD, FRCS (T&O), Department of Trauma and Orthopedics, Faculty of Medicine, Alexandria University, 228 Fawzi Moaz Street, Smouha, Alexandria 21648, Egypt  
Tel: +0020 155 527 2906;  
e-mail: Ahmed.abotaleb.clinic@gmail.com

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### Introduction

The proximal humeral locked plate (PHILOS) gained great popularity in the treatment of proximal humeral fractures which constitutes one of the common osteoporotic fractures, however, recent reports about failure in the treatment of comminuted fractures and those with diaphyseal extension led to different attempts of either augmenting or adding more fixation. Double plating is common in other peri-articular fractures. In this paper, the technique of double plating of the proximal humerus by adding a second plate to the PHILOS plate is described.

### Methods

Total 17 patients with comminuted fractures of the proximal humerus with diaphyseal extension treated between January 2109 and July 2022 performed at El-Hadra University Hospital with adding either a small locked dynamic compression plate or a small locked reconstruction plate with the standard PHILOS plate through the trans-deltoid approach.

### Results

The mean of the duration of the follow-up was 19.4 months $\pm$ 2.9 (range, 15–26 months). The mean age was 58.4 years of age $\pm$ 10.1 (range 36–68 years). There were five (29.4%) male patients, and 12 (70.6%) female patients. The mean number of units of transfused packed red blood cells was 1.8 units (range 1–3 units; SD 0.7). All patients achieved union without the need for secondary procedures like bone grafting and the average time till union was 6.7 months (range from 4.5–9.5 months; SD 1.7 months). At the end of the follow-up the average range of forward flexion was 165.4 $^{\circ}$  (range 150–177 $^{\circ}$ ; SD 8.2), and the average range of abduction was 166.2 $^{\circ}$  (range 150–175 $^{\circ}$ ; SD 7.8). Patients' average subjective satisfaction in the visual analogue scoring system was rated at 8.2 (range: 6–10; SD 1.3). At the end of the follow-up, the average Constant–Murley shoulder score was 88.1 (range 65–96; SD 7.6). The average Simple Shoulder Score was 77.9% $\pm$ 12.1% (range 50–92%). The mean University of California Los Angeles shoulder rating was 31 (range 24–34; SD 2.6). At the end of follow-up, the mean neck-shaft angle was 129.9 $^{\circ}$   $\pm$ 4.4 $^{\circ}$  (range, 123–138 $^{\circ}$ ), and after surgery, it was 131.1 $^{\circ}$   $\pm$ 4.6 $^{\circ}$  (range, 123–140 $^{\circ}$ ). Neck-shaft angle differences between the time of operation and follow-up were not statistically significant ( $P=0.7$ ). One patient who had preoperative radial nerve palsy recovered from the palsy in 6.5 months. Another patient had preoperative axillary nerve palsy recovered within 2 months. No other patients had preoperative or postoperative neurological injury.

### Conclusion

The double plating of the comminuted fractures of the proximal humerus with diaphyseal extension is safe and it does not add risk to either iatrogenic peripheral nerve injuries, humeral head vascularity, or shoulder impingement.

### Keywords:

comminuted fractures, diaphyseal extension, double plating proximal humerus, double plating, dual plating, osteoporotic fractures, proximal humeral fractures

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### Introduction

Proximal humeral fractures (PHF) constitute a significant part of osteoporotic fractures as well as fractures resulting from high-energy trauma with reported incidence in the age group older than 65 years old more than 250/100 000 individuals with more prevalence in females with increasing prevalence of

3- and 4-part fractures. The PHF is linked to considerable morbidity, mortality, and healthcare expenses [1–3].

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Such fractures are still a source of debate in literature with options of treatment varying from conservative care, open reduction and internal fixation, and hemiarthroplasty, to reverse total shoulder arthroplasty [4–7]. Surgical intervention is a common approach for treating PHFs using locking technology [7,8]. Elderly individuals undergoing plate fixation often experience increased complication rates, particularly those with osteoporosis [9–11]. The most common Complications include reduction loss, screw cut-out, and avascular necrosis [12].

The choice of treatment is generally influenced by the patient's general condition, fracture pattern, available resources, and surgeon's experience. These fractures have the potential of extending into diaphysis with disruption of the medial calcar which is critical in preventing varus collapse of such fractures with subsequent functional limitations. Despite the special emphasis given to varus-type fractures with different modalities of fixation, there's still a significant rate of failure with secondary varus displacement after osteosynthesis [13–15].

Such fractures, especially the comminuted ones have the possibility of causing the patient disability and chronic limitation of function if they do not heal in an acceptable position taking into consideration the patient's functional needs as well as the compensatory effect of the wide range of motion of the shoulder joint [16,17]. The calcar carries special importance in the stability of any fixation construct [14,18].

To deal with these issues and avoid the failure of reconstruction, different versions of proximal humerus locked plates (PHILOS) have been created [19,20]. Placing calcar screws in the inferomedial metaphysis enhances medial support and lowers the chances of fixation failure [21]. However, calcar screw and bone grafting were associated with a significant failure rate [14,22,23]. Extra screws can be utilized to enhance stability even more [24]. Cerclages or sutures are mainly employed for securing the tuberosities to the plate [25]. Later, the practice of double plating was introduced, where an additional plate is added to the anterior, posterior, or medial areas when using only one lateral locking plate does not offer enough stability in heavily fragmented fractures [26,27].

Bone augmentation was tried to improve medial support or metaphyseal void, filling can be done using either an autograft or an allograft. Initial good results were documented for fibular strut and cancellous bone in allogenic mode [28]. Alternatively, cement augmentation was introduced and it includes various

artificial compounds like calcium phosphate or polymethylmethacrylate that can be administered by injection to become liquid and solidify inside the body [25].

The addition of a second plate during fixation of the PHFs benefits resistance to torsional forces by adding the fixation screws in a different plane [20]. The literature describes various techniques for double plating. Most of the reported clinical outcomes involve the use of an additional one-third tubular plate over the lesser trochanter, anatomically shaped medial proximal locking plate, or locked distal-radius plate [16,26,29–32]. There are even reports about using two one-third tubular plates [33,34].

This paper describes the technique of using a PHILOS plate with either a small locked dynamic compression plate (DCP) or a small, locked reconstruction plate. The PHILOS plate was applied through a trans-deltoid approach to the lateral aspect of the proximal humerus covering most of the greater tuberosity. The small low contact plate or the small, locked reconstruction plate was applied just medial to the PHILOS plate with taking care to be lateral to the tendon of pectoralis major I.e.; lateral to the bicipital groove to avoid impinging against the tendon of the long head of the biceps.

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## Patients and methods

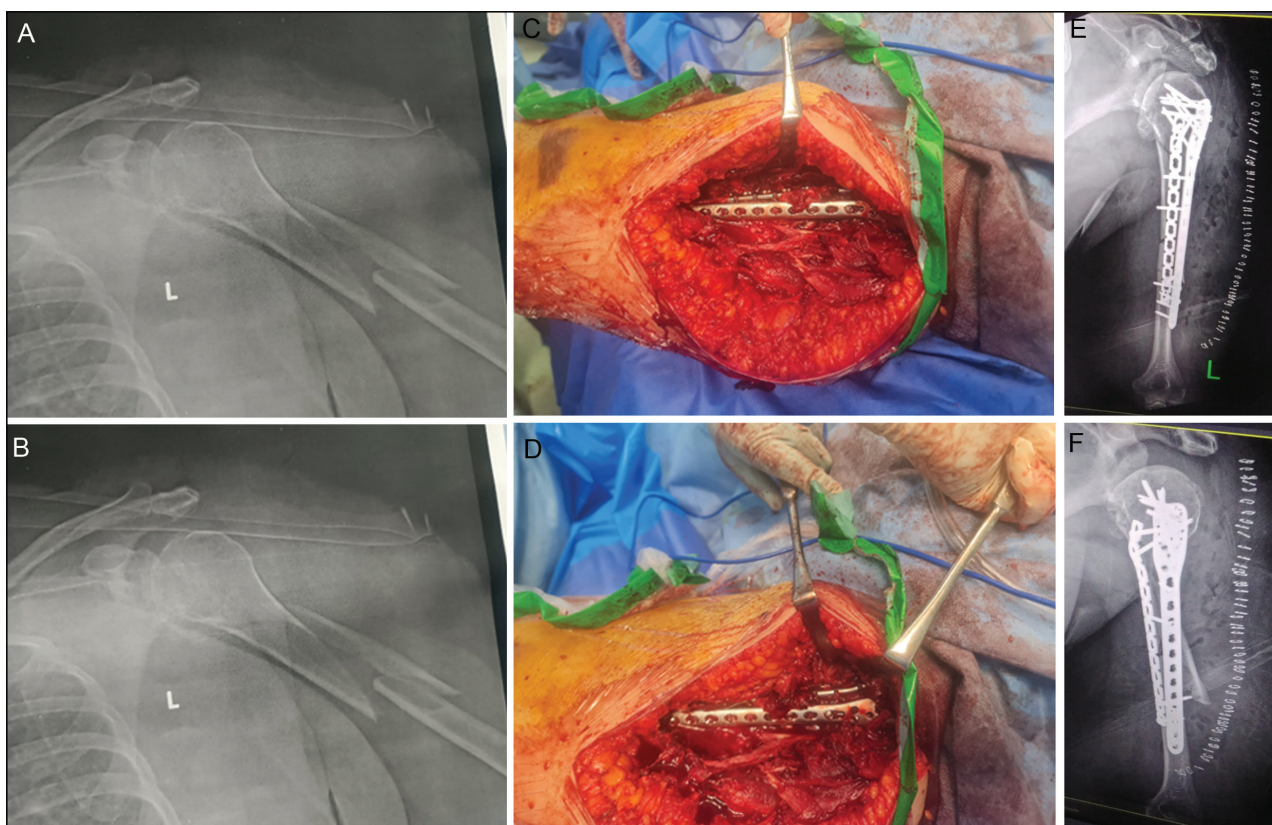
This paper describes the results of the treatment of 17 patients with comminuted fractures of the proximal humerus with diaphyseal extension treated between January 2019 and July 2022 performed at El-Hadra University Hospital.

The exclusion criteria were open fractures, pathological fractures, patients younger than 18 years of age, patients with previous neurological weakness of the injured limb due to previous injury or stroke, polytrauma patients, delayed/nonunion, concomitant shoulder dislocation, and patients who failed to have regular follow-ups for at least 12 months postoperative.

Originally 22 patients were operated on with this technique during the previously specified period, however, two patients died due to unrelated conditions during the period of follow-up and three patients did not present for follow-up after the first 9 months.

All patients consented to treatment after an explanation of all treatment options with their possible upsides and downsides results.

Figure 1



(a, b) preoperative radiography of 66 years old female who sustained fall downstairs, (c), an intraoperative photo showing the relationship between the two plates across the shaft, (d) intraoperative photo showing the proximal position of the two 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, f) are the postoperative radiography.

All patients were subjected to thorough primary and secondary surveys. Plain radiography was requested initially. Computed tomography scan was requested in some of the cases. Initial splinting was done with a broad arm sling. The operation was scheduled in the nearest available list after optimization of the general condition and the modifiable factors like transfusing packed red blood cells for the anemic patients.

A preoperative, intravenous single-shot antibiotic prophylaxis, following microbiology recommendation for the common surgical site causative organism sensitivity, is administered at least 30 min before incision.

Patients were positioned in about 15–20 anti-Trendelenburg positions with the use of radiolucent arm support and initial c-arm images were taken to make sure that the entire proximal humerus could be easily assessed by the c-arm during the procedure.

The patients were disinfected and draped. An opsite was applied to the surgical field. The trans-deltoid approach was then performed with the protection of the axillary nerve by limiting the proximal deltoid muscle splitting

to 2 inches under the acromion. Then splitting it distal to 4 inches below the acromion. Sutures were placed in the rotator cuff tendons to help reduce them and these sutures were attached to the PHILOS plate at the end of the fixation. Then with external rotation of the shoulder, the rotator interval became accessible, which helps the reduction of the intra-articular fracture lines.

Abduction of the shoulder was done when passing the plate under the muscle to effect elevation of the axillary nerve together with the posterior circumflex humeral artery from the humeral shaft thus avoiding its injury.

PHILOS plate is initially fixed proximally and distally with K-wires and image intensifier images were taken to confirm adequate position of the plate both proximally and distally and reduction of the fracture case example is shown in Fig. 1.

Then two nonlocking screws through the plate were inserted to ascertain the opposition of the plate against the bone interface. Then the rest of the screws were taken sequentially. The second plate was chosen to be one of either a small locked DCP or a small, locked reconstruction plate. The second plate was fixed in the



space between the PHILOS plate, and the pectoralis major tendon, and its proximal part was contoured so that it fits the shape of the underlying bone (Fig. 1). Then K-wire was inserted into one of the proximal holes of the second plate till one of the distal nonlocking screws was inserted to make sure that the plate is opposed to the bone then two locking screws were inserted in the proximal part of the plate. These two screws were always in a plane different from the locking screws of the PHILOS plate and were in a plane that would fix a head split fracture if there was one. Then, the distal screws of the second plate are inserted in a manner that would avoid the paths of the distal screws of the PHILOS plate. Care was taken so that screws from both plates did not end on the same level to avoid the stress riser effect.

Then final check images through an image intensifier were taken before the closure of the wound. The wound was closed in layers. Hemostasis was ascertained. There was no need to put radiovac in any of the cases.

#### Postoperative treatment

Postoperative medications included prophylactic antibiotics for the first 48 h, analgesics, and prophylactic

anticoagulation for 2 weeks. Plain radiography in two perpendicular views was taken immediately postoperatively and at follow-up visits. Neck-shaft angle was measured on the immediate anteroposterior view as well as the same view done during the last postoperative visit.

All the patients were allowed to start an active assisted range of motion in both forward flexion and pendular exercises as much as tolerated together with sling immobilization in between exercises. All patients were referred to an individualized rehabilitation program led by a physiotherapist.

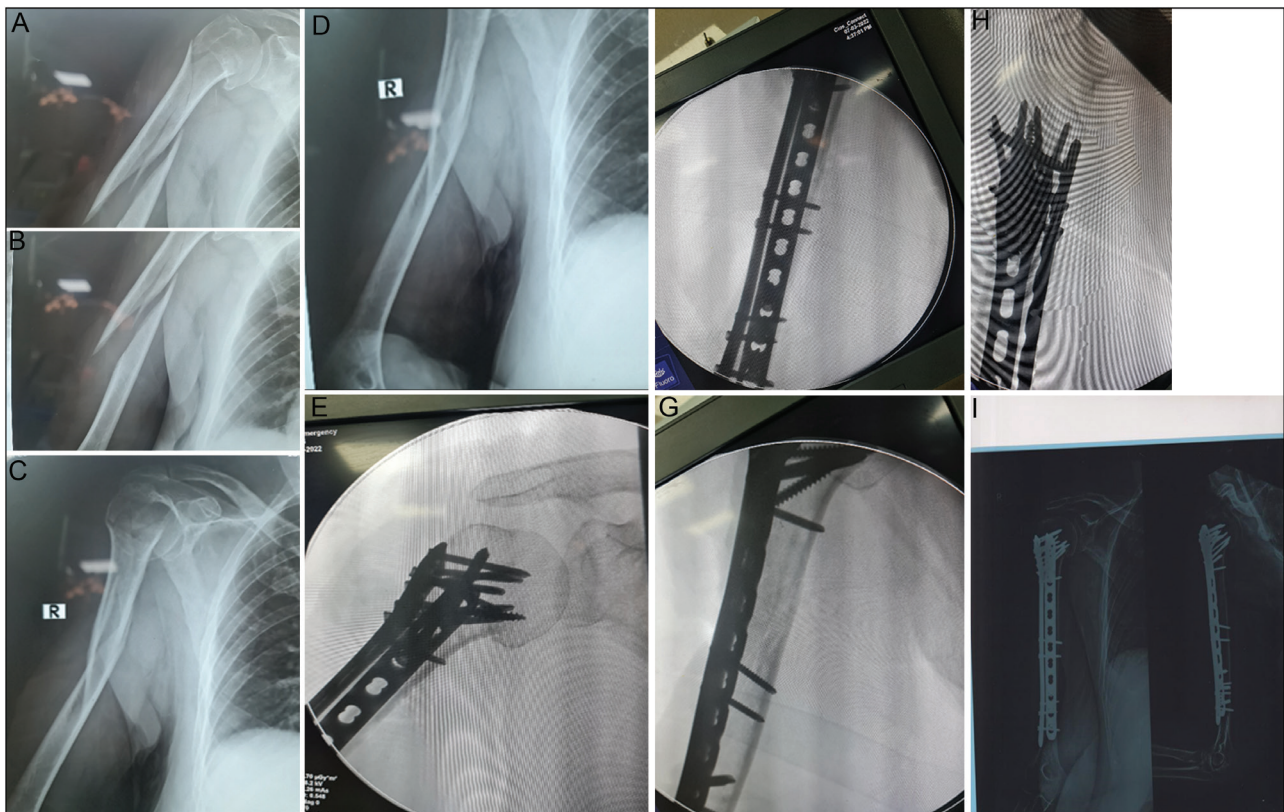
Bony bridging on plain radiography was the definition of radiographic union, which was verified by clinical examination (Figs 2, 3).

Failure was defined as either a need for a revision procedure to get the fracture united or the need for arthroplasty.

#### Statistical analysis

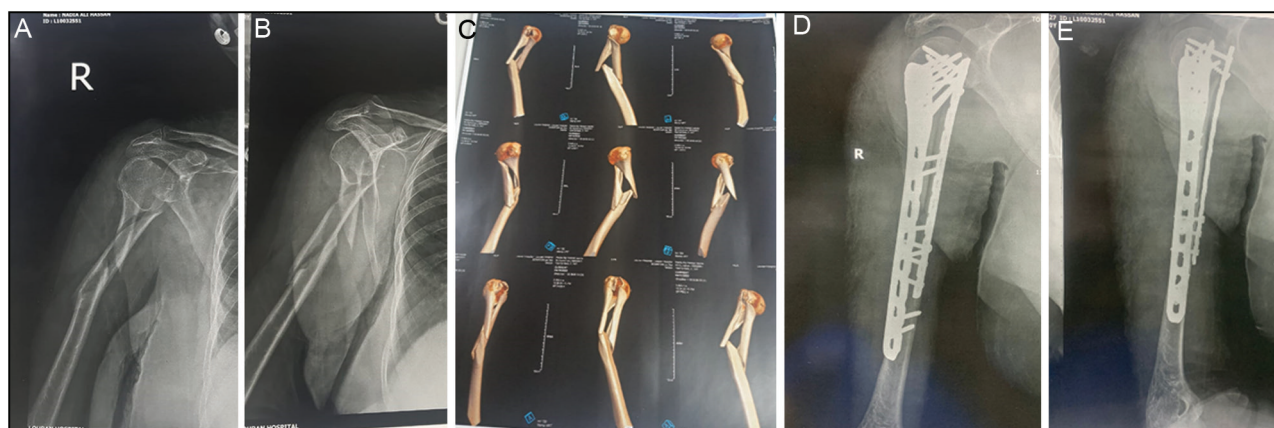
Numerical data was analyzed descriptively using averages, deviations, and spans. The results underwent

**Figure 2**



61 years old female was a victim of a road traffic accident as a pedestrian, (a–d) are the preoperative radiography, (e–h) is the intraoperative image intensifier photos after fixing the fracture with the two plates, I am the final radiography at the final follow-up, the fracture achieved union in 6 and half months.

Figure 3



64 years female who sustained a fall downstairs, (a, b) are the preoperative radiography, (c) is the preoperative reconstructed computed tomography images, (d, e) are the postoperative radiography.

testing to determine if they were within normal range. Determining normality was done through the Shapiro–Wilk test within the distribution. A *t*-test for independent means would have been used to compare results that follow a normal distribution. The Mann–Whitney *U* test was employed as a two-way analysis of variance to analyze independent factors for data that were not distributed normally. A significance level was determined to be below 0.05 based on the *P* value. Analysis was carried out with SPSS software (IBM SPSS Statistics 26, Chicago, Illinois).

## Results

The mean of the duration of the follow-up was 19.4 months $\pm$ 2.9 (range, 15–26 months). The mean age was 58.4 years of age $\pm$ 10.1 (range 36–68 years). There were five (29.4%) male patients, and 12 (70.6%) female patients. There were 14 (82.4%) patients having the fracture in their dominant limb, and three (17.6%) patients having their nondominant limb affected.

Only four (23.5%) patients had no associated medical comorbidities, eight (47.1%) patients had hypertension only, one (5.9%) patient had type 2 diabetes mellitus only, three (17.6%) patients had both hypertension and type 2 diabetes mellitus, and one (5.9%) patient had both hypertension and ischemic heart disease.

The mean interval between injury and fixation was 6.7 days (range 3–11 days; SD 2.4). The mean operative time was 137.1 min (range 110–175 min; SD 20.1). In seven (41.2%) patients the second plate was a small locked dynamic compression plate, while in the other 10 (58.8%) patients the second plate was a small, locked reconstruction plate. The mean number of units of transfused packed red blood cells was 1.8 units (range 1–3 units; SD 0.7).

All patients achieved union without the need for secondary procedures like bone grafting and the average time till union was 6.7 months (range from 4.5–9.5 months; SD 1.7 months).

One patient who had preoperative radial nerve palsy recovered from the palsy in 6.5 months. Another patient had postoperative axillary nerve palsy which was explored during fixation through the trans-deltoid approach and was found grossly intact and it recovered within 2 months. No other patients had preoperative or postoperative neurological injuries. None of the cases had superficial or deep surgical site infection. None of the patients had postoperative avascular necrosis of the humeral head, and neither needed an arthroplasty nor needed removal of the metalwork.

At the end of the follow-up the average range of forward flexion was 165.4° (range –177°; SD 8.2), the average range of extension was 36.7° (range 29–42°; SD 3.9), and the average range of adduction was 38.6° (range 30–45°; SD 4.9), and the average range of abduction was 166.2° (range 150–175°; SD 7.8), and the average range of external rotation was 46.2° (range 35–65°; SD 8.8), and the average range of internal rotation was 67.3° (range 50–75°; SD 7.4).

Patients' average subjective satisfaction in the visual analogue scoring system (VAS) was rated at 8.2 (range: 6–10; SD 1.3), with 0 representing the lowest satisfaction and 10 representing the highest satisfaction.

At the end of the follow-up, the average Constant–Murley shoulder score was 88.1 (range 65–96; SD 7.6). 14 (82.4%) patients had excellent results (>86 points), another two (11.8%) patients had good results (71–85 points), and one (5.9%) patient had fair results (56–



70 points). The average Simple Shoulder Score was  $77.9\% \pm 12.1\%$  (range 50–92%). The mean University of California Los Angeles (UCLA) shoulder rating was 31 (range 24–34; SD 2.6).

At the end of follow-up, the mean neck-shaft angle was  $129.9^\circ \pm 4.4^\circ$  (range, 123–138°), and after surgery, it was  $131.1^\circ \pm 4.6^\circ$  (range, 123–140°). Neck-shaft angle differences between the time of operation and follow-up were not statistically significant ( $P=0.7$ ).

## Discussion

In their study, Michel and colleagues reported two instances of avascular necrosis affecting the humeral head [35]. Not a single one of our cases suffered from Avascular necrosis of the humeral head. This is likely due to variations in the method used. The deltopectoral approach was utilized in their study, with the bicipital groove being compromised to perform tenodesis on the long head of the biceps tendon before placing the second plate on the lesser tuberosity above the subscapularis tendon insertion. Nonetheless, the series detailed in this paper employed the trans-deltoid approach, with the second plate positioned carefully adjacent to the pectoralis major tendon.

In their finite element analysis, He and colleagues compared the biomechanical performance of four constructs in normal and osteoporotic models, subjecting them to axial, shear, and torsional loads. The four configurations included a combination of a locking plate and a medial anatomical locking plate, a locking plate by itself, a locking plate with a fibular graft, and a locking plate with a distal radius plate. It was stated that using both a locking plate and a medial anatomical locking plate together resulted in the smallest change in neck-shaft angle, and higher overall and local construct stiffness compared with the other fixative techniques. Therefore, they suggested utilizing it to treat PHFs with an unstable medial column [29]. While the use of another anatomical plate applied directly to the medial cortex would inherently increase the stability of the construct, it raises many concerns about the safety of the approach with possible damage to the neurovascular structures and the tendons in this critical area. However, it endorses the idea of double plating hence the construct of the locking plate alone performed worse than the other three constructs in this study.

Earlier reports on attempts at double plating of the humerus include the paper by Wanner *et al.* who used two third tubular plates [33]. However, the fixation by two locking plates as in the current study will provide

significantly more fixation. This was proved by later studies including the study by Hessmann *et al.* [36].

Theopold and colleagues conducted a cadaver study where they compared the biomechanical effectiveness of using just a locking plate versus using a locking plate along with a third tubular plate inserted at the bicipital groove. They discovered that although the group with both plates showed increased stiffness at higher cycles, the difference was not statistically significant, and both groups had similar rates of failure [32]. This highlights the importance of using a strong plate as a second plate in the hybrid fixation of the complex fractures of the proximal humerus and coincides with our results as the third tubular plate with its low profile cannot withstand stresses at a major bone like the humerus and it was never used it even as a second plate.

Hessmann and colleagues conducted a study using cadavers to compare locking plates with double third tubular plates. The locking plate performed better than the double third tubular plates in every aspect of the study, as anticipated [36]. In the current study, a third tubular plate was not used either as a primary or secondary plate.

Theopold and colleagues in a clinical which included seven patients investigating the addition of a third tubular plate placed at the bicipital groove to the locking plate reported that the Constant shoulder score ranged from 58 to 94 (average 80), and VAS for patient satisfaction ranged from 0 to 6 (average 3), with two patients requiring re-operation during the follow-ups for metalwork removal and another patient requiring re-operation for avascular necrosis [31]. Even though recently the ascending branch of the posterior circumflex humeral artery was recognized as the principal source of blood supply to the humeral head, however it may be injured by any of the comminuted fragments, and thus the ascending branch of the anterior circumflex humeral artery becomes the remaining source of blood supply which highlights the importance of not violating the bicipital groove which was not done when treating any patients of this series, as well as none of them suffered from postoperative avascular necrosis or requested the removal of metalwork. As well the use of the locking technology in the second plate resulted in better in the current study as evidenced by Patients' average subjective satisfaction in the VAS was rated at 8.2 (range: 6–10; SD 1.3), the Constant–Murley shoulder score's average which was 88.1 (range 65–96; SD 7.6), the Simple Shoulder Score's average which was  $77.9\% \pm 12.1\%$  (range 50–92%), and the UCLA shoulder rating's mean which was 31 (range 24–34; SD 2.6).

In the current study, a combination of locked and nonlocked screws was used to ensure opposition of the plate to the shaft, thus minimizing its friction against the surrounding soft tissues. This also has been reported to have some other advantages as reported by Doornink *et al.* [37].

A recent study examined health insurance data from the Federal Association of Local Health Insurance Funds. It focused on patients over 65 from 2010 to 2018 and found a growing preference among surgeons for adding fixation with a locked plate, rather than using the locked plate exclusively. During the study period, there were observed changes in percentages: PHILOS decreased by 35%, PHILOS with extra fixation increased by 58%, and PHILOS with augmentation increased by 25%. Despite adding more fixation in increasing numbers of patients, only 10 patients (< 1% of cases) received double plating in 2018, indicating its complexity and surgeons may choose arthroplasty instead. They also stated that the hospital's total complication rate was 6211 (15%) and was highest among patients who received extra autologous bone augmentation, reaching 22% ( $n=17$ ) ( $P<0.001$ ). Similarly, in the subset of improvement, there were 213 (11%) patients with a significantly higher re-operation rate of 3202 (8%) patients in the total population ( $P<0.001$ ) [9]. In the current study, the use of the trans-deltoid approach facilitates exposure and allows for the two plates to be positioned lateral to the lateral lip of the bicipital groove, thus the technical difficulty was overcome.

In the current study, none of the cases experienced peri-implant fracture during the period of follow-up, and in all cases, the most distal screws in both plates were at different levels. This was endorsed by the cadaveric biomechanical study conducted by Hackl and colleagues who found that varying levels of screws in the two plates fixing the distal humeral fractures rather than plates configuration are significantly better in terms of resisting loads and thus protecting against peri-implant fractures [38].

Choi and colleagues used a deltopectoral approach with tenotomy of the long head of the biceps and extensive posterior dissection to insert a variable angle distal radius locked plate posterior to the greater tuberosity together with the locking plate placed laterally over the greater trochanter in 21 patients and reported one case of impingement and one case of avascular necrosis and that at the final follow-up, the average Constant score was 90.4 points, with a range of 72–96 points, and all patients fully regained shoulder range of motion. The UCLA shoulder rating scale scored 23 points at the final follow-up, with

a range of 21–35 points [16]. In the current study, extensive dissection either anteriorly or posteriorly was avoided and neither any of the two plates violated the bicipital groove. None of the cases in the current study suffered postoperative avascular necrosis or impingement. In the current study The mean UCLA shoulder rating was 31 (range 24–34; SD 2.6), and, the average Constant–Murley shoulder score was 88.1 (range 65–96; SD 7.6).

Up till now, the lines between choosing fixation versus arthroplasty for comminuted fractures of the proximal humerus in the elderly are somewhat blurred and still heavily affected by the skills of the treating surgeon and the affordability of significantly more expensive arthroplasty. For example, Antonios *et al.* reported good outcomes after arthroplasty for comminuted fractures of the proximal humerus in the elderly [39].

The current study shows that double plating of the proximal humerus is possible in a safe manner without adding neurological risk to the limb, risking the vascularity of the humeral head, or risking postoperative shoulder impingement. Further studies involving a larger number of patients and longer follow-up periods are required to ascertain the results of the current study Figs 1–3.

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Nil.

#### Conflicts of interest

There are no conflicts of interest.

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