



Lateral minimally invasive plate osteosynthesis (MIPO) with long PHILOS for proximal metaphyseal-diaphyseal humeral fracture: surgical techniques and a clinical series

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Received: 15 August 2023 / Accepted: 27 August 2023 / Published online: 9 September 2023
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Abstract

The minimally invasive plate osteosynthesis (MIPO) for proximal metaphyseal-diaphyseal humeral fracture is an effective alternative treatment with satisfactory outcomes. In this study, we described the surgical techniques and clinical results using MIPO via a lateral approach and long PHILOS plate fixation in 23 patients. All fractures were successfully united within a mean union time of 13.5 weeks (range 9–18). There was no iatrogenic radial nerve palsy. The deltoid power was grade 5 in all patients, except for 2 patients who had associated brachial plexus injury and gunshot injury at the deltoid muscle. The mean Constant–Murley score was 85.6 (range 16–98) and DASH score was 12.1 (range 1.7–85). Based on these findings, the lateral MIPO with long PHILOS plate fixation could be an alternative for the proximal metaphyseal-diaphyseal fractures of the humeral shaft.

Keywords MIPO · Long PHILOS · Humeral fracture

Introduction

Humeral shaft fractures represent 1–3% of all fracture [1] and are generally treated conservatively with successful outcomes. However, the proximal third of the humeral shaft is considered at risk for non-union, and surgical stabilization is considered a reliable option [2]. Plate osteosynthesis is preferred over intramedullary nailing in these fractures to reduce the risk of shoulder problems or iatrogenic radial nerve injury [3]. In recent years, minimally invasive plate osteosynthesis (MIPO) has emerged as a promising surgical

technique and demonstrating good results in humeral fractures [4, 5]. It offers adequate stability without interfering with the vascularity of the fracture zone, allowing for early functional after treatment resulting in favorable healing and clinical outcomes. The proximal humeral internal locking system (PHILOS) plate (Fig. 1) is generally considered the implant of choice for this unique fracture due to its angular stability with multiple locking screws for short proximal fragments and anatomical contour. These combined benefits make MIPO with long PHILOS plate an attractive option for treating proximal metaphyseal humeral fractures. However, the major concerns are the risk of axillary nerve injury at the proximal incision and iatrogenic radial nerve injury at the distal incision when using the long plate and the disturbance to the deltoid muscle insertion during submuscular positioning of the plate along the lateral aspect of the humerus [6]. To minimize these risks, the helical plate concept was introduced, with the proximal part of the plate positioned on the lateral aspect and the distal part positioned on the anterior or anterolateral aspect [7]. Nevertheless, concerns remain regarding the strength reduction of the plate from manual twisting and the potential destruction of the locking mechanism.

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Fig. 1 The anterior and lateral view of the PHILOS plate

Previous clinical studies demonstrated the excellent outcomes and safety of the radial nerve with the use of MIPO with long PHILOS [7–10]. However, no study reported the clinical relevance of the deltoid muscle insertion injury related to this procedure.

In the current series, we combined the benefits of lateral MIPO with long PHILOS plate fixation to treat proximal metaphyseal-diaphyseal fractures of the humerus. We describe the surgical technique, as well as the radiological and clinical results, including the deltoid muscle function associated with this approach.

Materials and methods

Between January 2018 and December 2022, a retrospective case series of 23 patients with proximal metaphyseal-diaphyseal fractures of the humerus was conducted at the trauma unit in two tertiary centers. The surgical technique used was MIPO with long PHILOS plate. The inclusion criteria for the study were a closed type B or C (wedge or comminuted) fracture of the proximal humeral shaft (AO/OTA 12) and age more than 18 years. Patients with pathologic fractures, periprosthetic fractures, and those under 18 years of age

were excluded. Demographic data, cause of injury, associated injury, fracture configuration by the AO/OTA classification and time-to-operate were recorded.

Surgical technique

After general anesthesia, the patient was positioned supine on a radiolucent table, and the affected arm was draped sterilely for intraoperative manipulation. Prophylaxis antibiotic was administered. The operation started with a 5-cm incision being made from the anterolateral edge of the acromion extended distally along the lateral aspect of the shoulder (Fig. 2). The raphe between the anterior one-third and posterior two-thirds of the deltoid muscle was identified, and dissection was carried down between this interval to reach the subdeltoid bursa. The bursa was incised, exposing the rotator cuff over the greater tuberosity. Sutures were used to tag the rotator cuff and assist in proximal fragment manipulation. An axillary nerve was not formally dissected but was identified by finger palpation. Distally, a 5-cm distal incision was then made over the lateral aspect of the affected arm using the 8- to 10-hole long PHILOS plate to approximate the location of the incision. The dissection was carried down to the interval of the brachialis and brachioradialis muscles to identify the radial nerve. The radial nerve was gently released to the lateral intermuscular septum to facilitate further mobilization while carefully protecting the nerve throughout the surgical steps. A submuscular tunnel under the deltoid muscle was initiated using a tunneller or the plate itself (Fig. 3). The middle part of the deltoid insertion was bluntly released using periosteal elevator or Cobb elevator to prepare an adequate area for lateral plate position. An 8- to 10-hole long PHILOS (Synthes, Oberdorf, Switzerland) was selected and passed through the submuscular tunnel, under the axillary nerve, from proximal to distal direction. To minimize nerve injury, it was recommended to slightly abduct the shoulder and use finger to protect the axillary nerve during plate insertion. Special attention was given to the radial nerve while the plate passed through the distal incision. The proximal portion of the plate was positioned 5–8 mm below the tip of the greater tuberosity and 5 mm lateral to the bicipital groove. An image intensifier was used to verify the implant's position. A locking sleeve was inserted into a locking part of the proximal plate hole, followed by K-wire to temporary secure the plate in proper position. Then, locking screws were inserted into the proximal fragment. Fracture shortening was corrected by steady longitudinal traction, and then the plate was reduced to the distal fragment using a conventional screw after being properly aligned on the distal fragment (Figs. 4, 5). In case where achieving acceptable alignment through closed methods was unsuccessful, mini-open reduction was considered (Fig. 6). The fracture and implant position were verified by an image intensifier, and

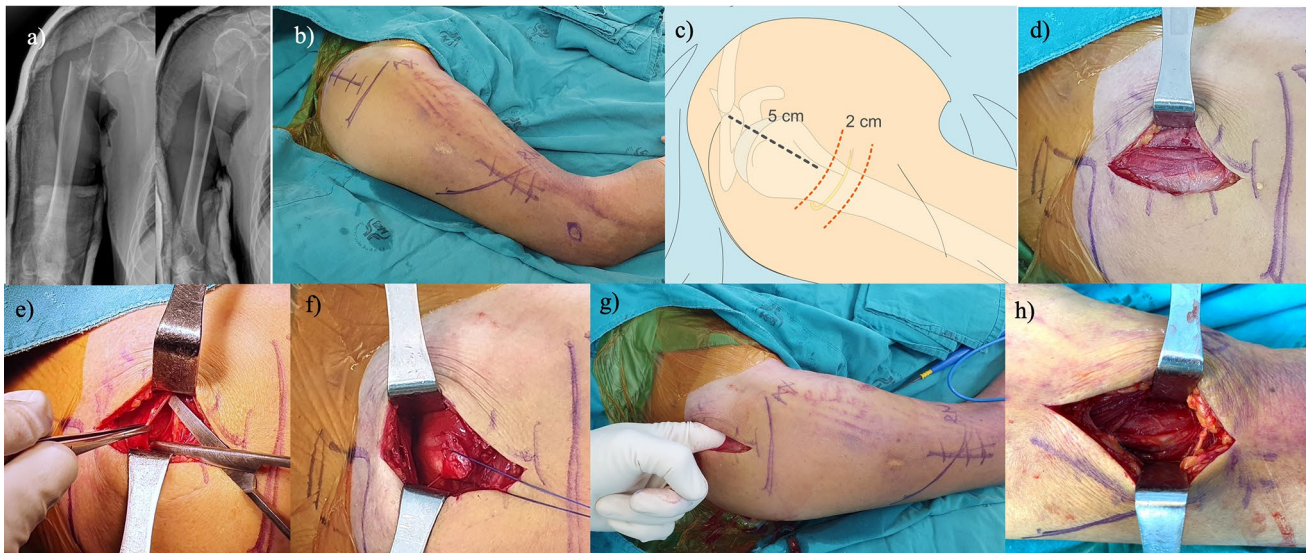


Fig. 2 a Wedge fracture of the left proximal humerus. b Drawing demonstrating proximal and distal incisions. c Illustration of the proximal incision. d Plane between the anterior 1/3 and posterior 2/3

of the deltoid. e Incised bursa. f Cuff suture used for manipulation. g Finger palpation to identify the axillary nerve. h Distal incision with identification of the radial nerve

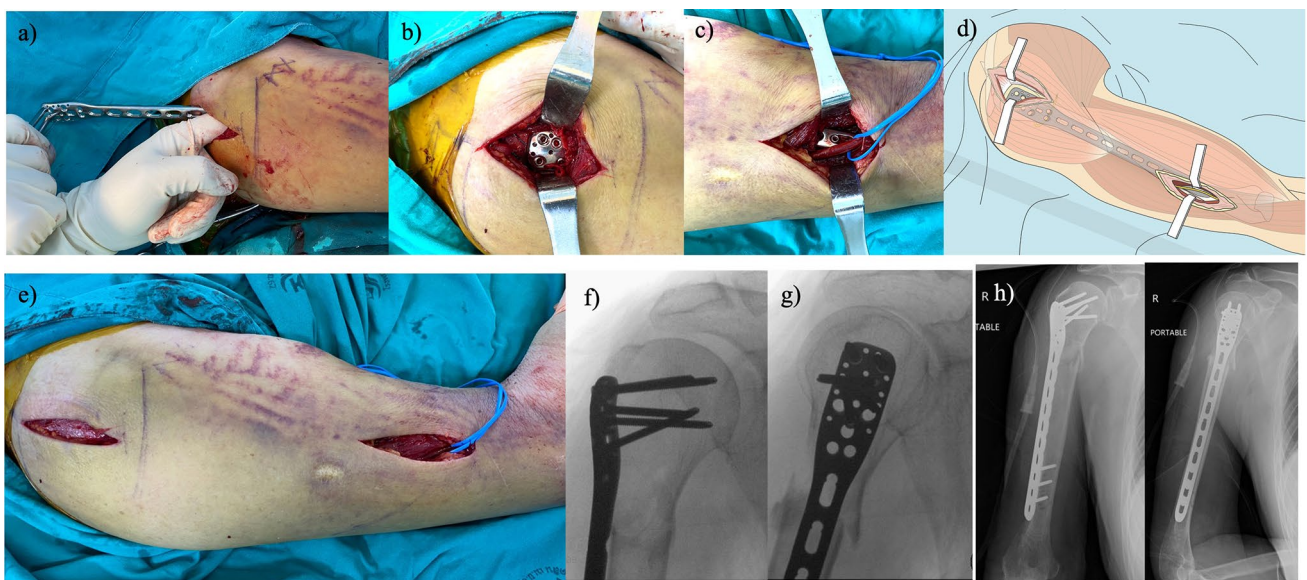


Fig. 3 a Submuscular tunneling. b–d Final plate positioned underneath the radial nerve. e Surgical incision for the MIPO approach. f–g Intraoperative fluoroscopy. h Post-operative radiograph

then the remaining screws were inserted into both fragments. To achieve sufficient fixation, it was necessary to use five to six screws in the proximal fragment and a minimum of three screws in the distal fragment. Furthermore, the cuff sutures were secured through the plate hole to further enhance the fixation. If segmental fracture was present and the middle part of the fracture remained unstable after proximal and distal screws insertion, an additional screw was inserted at the middle part. At the final fixation, the radial nerve crossing

over the plate in the distal incision had to be directly visualized. The surgical wounds were closed over a vacuum drain.

The drain was removed 2 days after surgery, and physiotherapy was encouraged to restore elbow and shoulder motion. Radiographic evaluation, including fracture alignment and bone healing, was determined during the immediate post-operative period, 2, 6, 12, and every 4 weeks until bone union. Clinical evaluation, consisting of post-operative complications, range of motion, deltoid power by Medical

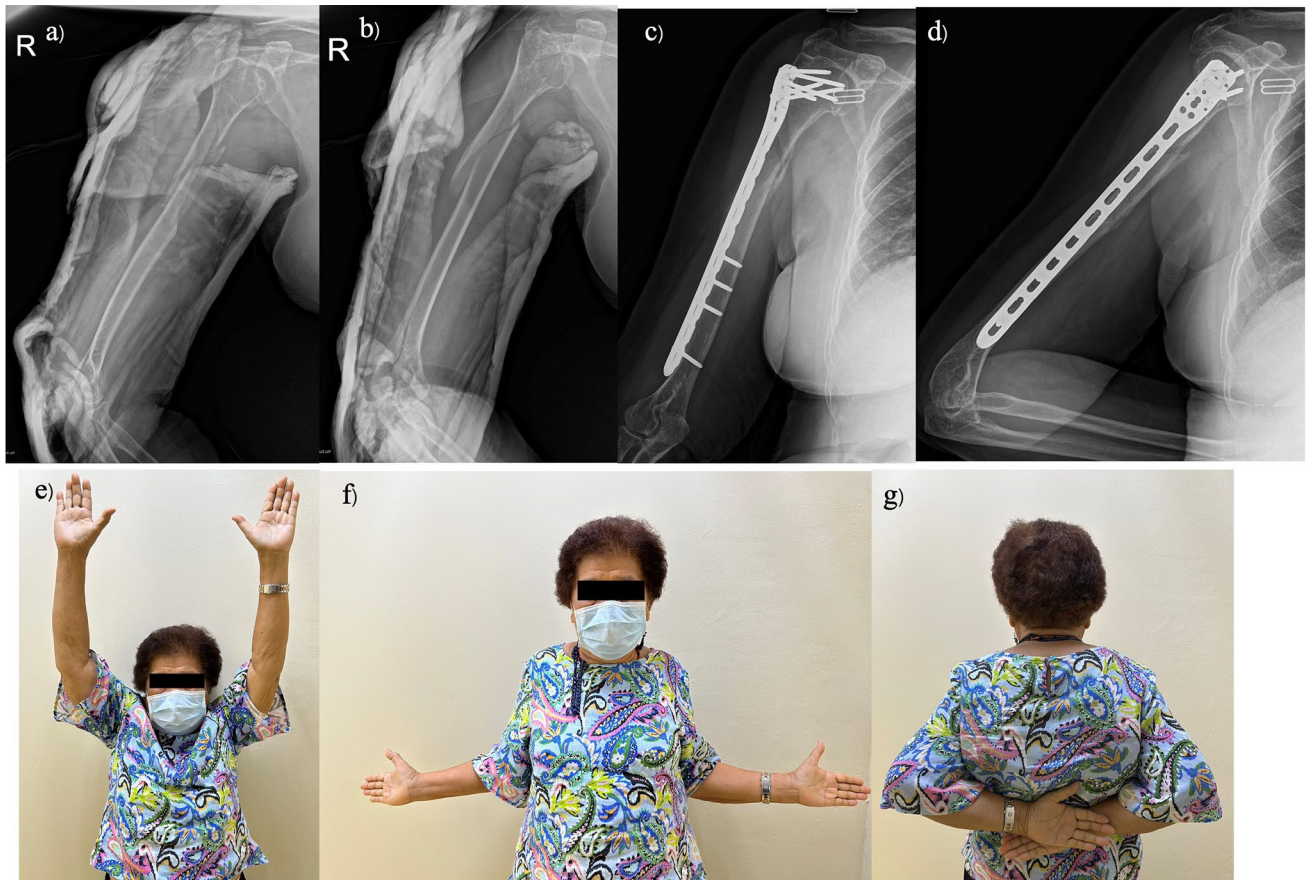


Fig. 4 a, b Wedge fracture of the left proximal humeral shaft. c, d Post-operative radiographs of MIPO with long PHILOS plate fixation. e, g Clinical outcomes assessed at 6 months post-operatively

Research Council (MRC) grading, Disabilities of the Arm, Shoulder and Hand (DASH) and Constant–Murley shoulder score, was determined and recorded.

Results

The present case series included 11 males and 12 females with a mean age of 48 years (range 20–82). Twelve patients affected in the right side (52%). The cause of injury was motorcycle accident in 14 patients (60%), falling in 7 patients (30%) and gunshot injury in 2 patients (10%). The AO/OTA classifications recorded included 12B ($n=11$) and 12C ($n=12$). The mean time-to-operate was 7 days (range 1–35) (Table 1).

The mean follow-up time was 10 months (range 6–30). All fractures were united in an average of 13.5 weeks (range 9–18). There were 4 patients with initial radial nerve palsy, three of them recovered during follow up while another patient did not show improvement regarding the associated brachial plexus injury. No iatrogenic radial nerve injury was found, and no apparent deformities were observed in any of

the patients. The deltoid power was Grade 5 in 21 patients. One patient was Grade 0 regarding associated total-arm-type brachial plexus injury and one patient was grade 3 due to significant injury of the deltoid muscle from gunshot injury. The mean Constant–Murley score was 85.6 (range 16–98) and DASH score was 12.1 (range 1.7–85) (Table 2).

Discussion

The surgical treatment of proximal humeral shaft multifragmentary fractures is a complex procedure in trauma practice. There is currently no established consensus on the optimal treatment for proximal metaphyseal–diaphyseal humeral fractures. Treatment options include open reduction internal fixation, antegrade intramedullary nailing (IMN) and MIPO. The IMN is a minimal invasive surgical approach that enables satisfactory reduction with minimal incisions. Outcomes, in terms of fracture consolidation and functional results, have shown comparability to those of MIPO [11]. However, a major concern revolves around the potential risk of rotator cuff injury, which may subsequently lead to

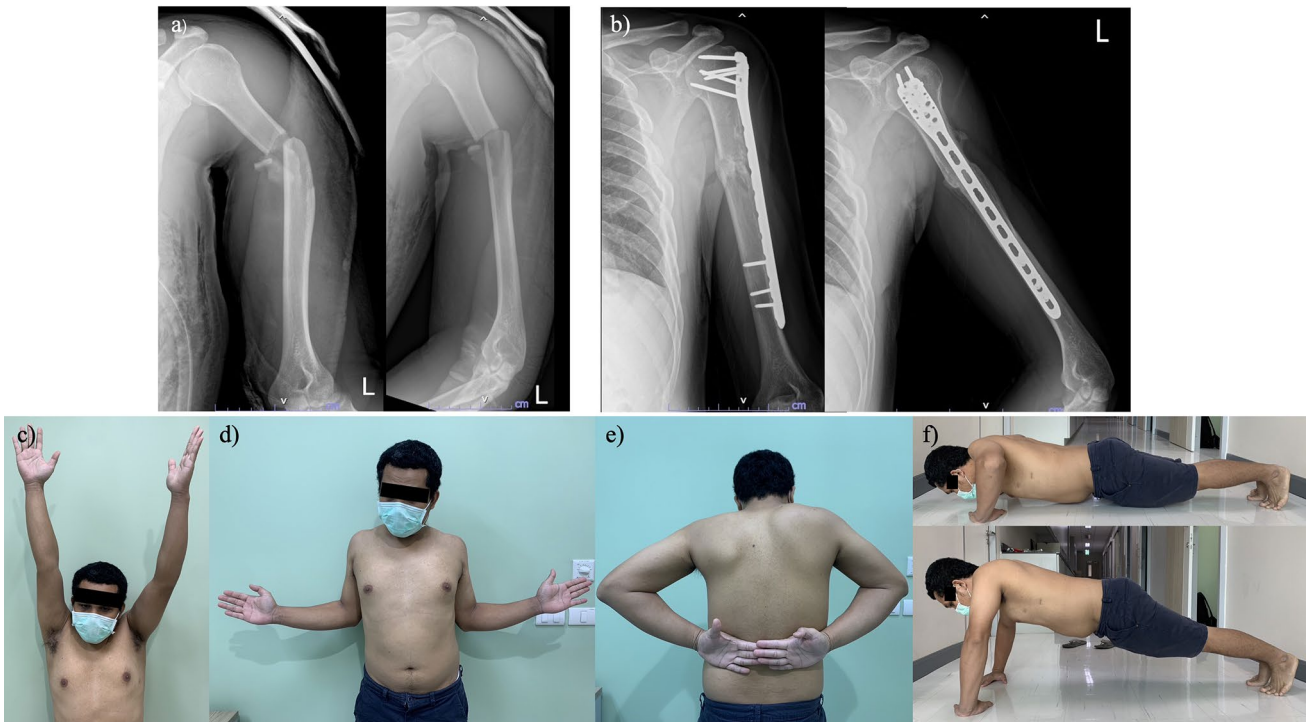


Fig. 5 a Wedge fracture of the left proximal humeral shaft. b Post-operative radiograph showing MIPO with long PHILOS. c–f Clinical outcomes evaluated at 1 year post-operatively



Fig. 6 a, b Segmental fracture involving proximal metaphyseal-dia-physeal of the left humeral shaft. c Mini-open reduction performed at the distal fracture site and stabilized with cerclage. d MIPO with long PHILOS plate fixation. e–h Radiographic and clinical outcome assessed at 8 months post-operatively

Table 1 Demographic and clinical characteristics

Patient no	Sex	Age (years)	Side	AO/OTA classification	Associated injury	Cause of injury	Time-to-operate (days)
1 (Fig. 4)	F	77	R	12 B2	Patellar fracture	Motorcycle accident	5
2	M	69	R	12 C2	None	Falling	5
3	M	32	L	12 B3	Distal clavicular fracture, pneumothorax	Motorcycle accident	1
4	F	45	R	12 C3	None	Motorcycle accident	4
5	F	32	L	12 C2	None	Motorcycle accident	11
6 (Fig. 6)	F	69	L	12 C3	None	Motorcycle accident	8
7	F	62	R	12 C3	Base of skull, maxillofacial, pelvic and distal femoral fracture	Motorcycle accident	5
8	F	50	R	12 B3	None	Falling	5
9 (Figs. 2,3)	M	82	R	12 B2	None	Falling	5
10	M	30	L	12 C2	Distal radius and maxillofacial fracture, brachial plexus injury	Motorcycle accident	8
11 (Fig. 5)	M	31	L	12 B2	Ankle fracture, hemothorax	Motorcycle accident	4
12	M	42	R	12 C3	Clavicular fracture and total-arm-type brachial plexus injury	Motorcycle accident	35
13	M	42	R	12 B2	None	Motorcycle accident	8
14	F	50	L	12 B2	None	Falling	1
15	M	56	L	12 B2	None	Falling	7
16	M	33	L	12 C3	None	Motorcycle accident	16
17	F	20	R	12 C2	None	Motorcycle accident	3
18	F	80	L	12 B2	None	Falling	1
19	M	65	L	12 B3	None	Motorcycle accident	3
20	F	30	L	12 C2	None	Motorcycle accident	8
21	F	50	R	12 C3	None	Falling	16
22	F	34	R	12 C3	Clavicular fracture and contralateral humeral fracture	Gunshot injury	7
23	M	27	R	12 B3	None	Gunshot injury	7

post-operative shoulder issue [12]. To address this concern, newer nail designs have been developed, featuring a straight nail design and a shift the point of entry towards a more medial position. This modification aims to minimize damage to the supraspinatus footprint, thereby reducing the risk of complications [11, 13].

The MIPO technique for the humeral shaft fracture aims to provide stable fixation while preserving the biological integrity. This method, specifically through the anterior approach, has proven to be versatile in managing multifragmentary fractures of the humeral shaft with a low risk of radial nerve injury and favorable outcomes [5, 14]. However, in situations where proximal metaphyseal fractures present a limited fixation area, the PHILOS plate positioned on the lateral aspect of the proximal humerus is considered the preferred implant for this specific region.

MIPO with long PHILOS has been shown to be effective in managing proximal humeral fracture, providing adequate fixation with multiple locking screws in the proximal fragment. However, the lateral MIPO approach raises concerns due to the proximity of the axillary and radial nerves to the

implant, increasing the risk of radial nerve injury and making the application of reduction devices technically challenging. Careful handling during the procedure is crucial to avoid iatrogenic nerve injury. In a series of lateral MIPO in 17 proximal humeral shaft fractures by Jeong et al. [15], one patient experienced post-operative temporary radial nerve palsy. Similarly, Touloupakis et al. [16] reported one case of transient radial nerve palsy in a series of 11 proximal humeral shaft fractures treated by straight or helical plate. In contrast, Rancan et al. [8] demonstrated no iatrogenic radial nerve palsy in a series of 29 patients with proximal metadiaphyseal fractures treated with MIPO long PHILOS.

In our study, we examined 23 patients with proximal humeral shaft fractures who underwent MIPO with long PHILOS plate fixation. The results were promising, as all patients achieved satisfactory radiographic and clinical outcomes, additionally, there were no cases of iatrogenic nerve injury observed during the treatment. We emphasized the importance of adequate surgical technique, including initial reduction prior to preparing the submuscular tunnel, adequately prepare the space at the deltoid insertion,

Table 2 Radiographic and clinical outcomes

Patient no	Plate length (hole)	Time to union (week)	Residual angulation in coronal plane (degree)	Residual angulation in sagittal plane (degree)	Deltoid power (MRC grading)	DASH score	Constant–Murley score	Follow-up time (months)	Complication
1 (Fig. 4)	10	13	–	Anterior 5°	5	13	87	6	None
2	10	14	–	–	5	18	54	5	None
3	8	12	–	–	5	18	90	6	None
4	8	13	Varus 5°	–	5	17	90	9	None
5	10	18	–	–	5	17	87	9	Radial nerve neurapraxia (pre-operative–recovered)
6 (Fig. 6)	10	9	Varus 5°	–	5	12	89	8	Radial nerve neurapraxia (pre-operative–recovered)
7	8	12	–	–	5	6	90	20	None
8	10	13	–	–	5	6	97	7	None
9 (Figs. 2,3)	10	12	–	–	5	2	94	8	None
10	10	18	–	–	5	13	85	6	Radial nerve neurapraxia (pre-operative–recovered)
11 (Fig. 5)	10	13	–	–	5	2	98	12	None
12	8	16	–	–	0	85	16	8	Radial nerve neurapraxia (pre-operative–not recovered)
13	10	15	–	–	5	3	94	9	None
14	8	13	–	–	5	8	87	12	None
15	10	13	–	–	5	9	87	7	None
16	10	14	–	–	5	8	96	7	None
17	10	13	–	–	5	6	90	6	None
18	8	14	–	Posterior 5°	5	6	90	30	None
19	8	14	–	–	5	12	88	12	None
20	10	13	–	–	5	8	86	5	None
21	8	11	Varus 5°	–	5	5	90	7	None
22	10	14	Valgus 10°	–	3	5	86	7	None
23	10	13	–	–	5	2	98	23	None

gently retraction of the nerve and insertion of the plate to prevent this complication. In the current series, there was no instances of iatrogenic radial nerve palsy, and all patients with initial radial nerve palsy showed recovery at final follow-up, except one who had a total-arm-type brachial plexus injury.

The helical plate concept was introduced to avoid the risk of radial nerve injury by positioning the distal part of the plate away from the nerve. The surgical approach involved a proximal incision via lateral deltoid splitting and a distal incision via anterior splitting approach. In a study by Brunner et al. [7], no iatrogenic radial nerve palsy was observed

in a series of 16 patients of proximal humeral shaft fracture treated with MIPO using long helical plate. All fractures united and achieved a satisfactory functional outcome. Similarly, Wang et al. [17] reported no radial nerve palsy with helical plate in their series. On the other hand, Basal et al. [9] recently reported two cases of radial nerve palsy when using a 30-degree helical plate with a lateral distal incision. Considering this, the “helical plate concept” may be considered as an alternative in this fracture pattern. The drawback of the helical plate includes the difficulty of plate twisting and the deformation of the locking hole, which may affect stability.

Deltoid muscle weakness is one of the concerns as it needed to be released from the deltoid insertion to allow for lateral plate position. To overcome these problems, a special design of the plate was considered, including one that was manually contoured into a helical shape or pre-contoured by the manufacturer, such as the ALPS plate (Biomet Trauma; Zimmer Biomet, Warsaw, IN, USA). Benninger and Meier [6] conducted a cadaveric study to demonstrate the injury of the deltoid muscle insertion following the MIPO with long PHILOS and found that most of the anterior and posterior parts of the insertion were preserved while the middle parts were damaged, however, the clinical relevance remained unclear. In another study, Ekdahl et al. [18] revealed the injury of the anterior part of the deltoid insertion in MIPO with a new precontoured long locking plate (ALPS plate, Zimmer Biomet). They found that the deltoid insertion was partially compromised in all cases. Nevertheless, the clinical significance was debatable and remained unclear. In our study we released the middle part of the deltoid from the insertion with the width of 4–5 cm to allow plate movement during the reduction procedure, the approach detached the deltoid insertion beneath the intact skin and muscle which still cover the superficial part of the deltoid, the functional deficit or weakness should be minimal. We observed favorable strength in the deltoid muscle function in the majority of all patients, resulting in good functional outcomes. This finding supports the notion that the intact strongest anterior and posterior deltoid muscles with tunnel perforation under the middle deltoid were sufficient to provide a positive functional outcome in this lateral plate location [19].

Regards to the outcome, several studies demonstrated the excellent union rate [7–9, 16, 17]. The Constant–Murley score was reported in 77–90 [7, 9, 17] and DASH in 29–33 [7, 16]. Our series supported these findings included the mean Constant–Murley score, which was found to be 85.6 (range 16–98), indicating favorable functional outcomes. Additionally, the DASH score, reflecting upper extremity disability, showed a mean of 12.1 (range 1.7–85), further supporting the positive results of this treatment approach.

Based on the findings, it can be recommended that lateral MIPO with long PHILOS plate fixation offers a viable and promising alternative for managing proximal metaphyseal-diaphyseal fractures of the humeral shaft.

Conclusion

Regarding fracture union and functional outcome, lateral MIPO with long PHILOS fixation is an alternative for multifragmentary fractures of the proximal metaphyseal-diaphyseal humeral shaft fracture. Meticulous dissection of the radial nerve in distal incision was recommended to avoid the iatrogenic injury. Even in the presence of an unavoidable

deltoid insertion injury, the strength of the deltoid muscle remains satisfactory.

Author contributions CJ were involved in drafting and revising the manuscript for content, including medical writing for content, study concept and design, analysis and interpretation of data, as well as acquisition of the data. PR was involved in data collection and drawing illustrations. PA was involved in data collection and analysis. PT, TL and TA were involved in revising the manuscript for content and analysis and interpretation of data.

Funding There was no source of funding for this research.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This study has been approved by the ethical committees of Queen Savang Vadhana Memorial Hospital in accordance with the Declaration of Helsinki.

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