Case Series

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Medial minimally invasive plate osteosynthesis for humeral shaft fractures: a case series

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Background: Minimally invasive plate osteosynthesis (MIPO) is increasingly favored for treating humeral shaft fractures (HSFs). However, conventional MIPO techniques pose challenges in fixing fractures near the fossa olecrani and carry a high risk of iatrogenic radial nerve palsy. This study was aimed to report the clinical outcomes of a series of patients who underwent MIPO through a medial approach for HSFs and describe our treatment algorithm.

Patients and Method: This is a study conducted in our university hospital, which is a Level 1 academic trauma center. A retrospective analysis of 21 patients with HSFs who received minimally invasive treatment using plate osteosynthesis through a medial approach over a 5-year period was conducted. The outcomes measured included time for radiographic consolidation, disabilities of the arm, shoulder, and hand score, and complications such as infection, iatrogenic radial nerve injury, loss of reduction or fixation, and nonunion.

Results: Twenty-one patients who underwent the procedure were identified. Bone healing was achieved in all patients with an early and aggressive range of motion. There were no cases of infection or iatrogenic radial nerve injury. The mean radiographic fracture union time was 15.76 weeks (range: 8–40 weeks). The mean disabilities of the arm, shoulder, and hand score was 3.29 (range: 0–14.17) at the time of the last follow-up. The mean screw density was 0.43.

Conclusion: The proposed algorithm is effective in addressing the challenges of iatrogenic nerve injury and extra-articular distal fixation of HSFs with conventional MIPO techniques.

Keywords: approach, complications, humeral shaft fractures, minimally invasive plate osteosynthesis, retrospective case series

Background

Historically, nonoperative management for acute, isolated, and closed humeral shaft fractures (HSFs) has been the preferred choice of orthopedic surgeons due to the belief in low rates of delayed union, nonunion and the complications of open reduction and internal plate fixation (ORIF) as well as the shoulder's ability to compensate for angular and rotational malalignment[1].

It is considered acceptable that the HSFs heal up with less than 20° of angulation in the anterior-posterior plane, less than 30° of Varus/valgus angulation, less than 15° of malrotation, and less than 3 cm of shortening following functional brace treatment, and these will most unlikely change upper-limb function or esthetics[2,3]. There has been little debate regarding the validity of these values ever since 1966 when Klenerman published the observation that function is preserved within these measurements[4].

However, functional treatment can lead to unsatisfactory results, including a high incidence of nonunion and malunion and limb impairment, and it may also present more difficulties for obese patients and those with large breasts[5]. On the other hand, the nonunion rate ranges from 4 to 13% and the infection rate is up to 3% after ORIF. Radial nerve palsy is also a common complication of ORIF with a plate, as was reported in up to 7% of patients[1]. Over the past two decades, as the application of minimally invasive plate osteosynthesis (MIPO) for HSFs showed good results, MIPO has been used as an alternative to nonoperative management and ORIF, and the concept in plate fixation for HSFs has changed from absolute to relative stabilization[6–8].

HIGHLIGHTS

- The manuscript is the first in the world to address the advantages of medial minimally invasive plate osteosynthesis (MIPO) for humeral shaft fractures (HSFs) and to describe our creative treatment algorithm.
- The algorithm reported in the manuscript can solve the problems of iatrogenic nerve injury and extra-articular distal fixation of HSFs with conventional minimally invasive plate osteosynthesis techniques. Furthermore, we have identified three issues for HSF surgery that need to be addressed, which are discussed in detail in this paper.

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Table 1

Patient Demographics.

Variable	No
Total no. of fractures	21
Lost to clinical follow-up	0
Average age (range) years	43.9 years (range: 22–81)
Male	13
Female	8
Smokers	7

MIPO for HSFs had been reported using anterior, anterolateral, and posterior approaches. Conventional MIPO techniques have been associated with difficulty in the fixation of the HSFs near the fossa olecrani and a high incidence of iatrogenic radial nerve palsy.

To the best of our knowledge, medial minimally invasive plate osteosynthesis has never been described for isolated HSFs. The purpose of this article was to compare the clinical results of our series with those of conventional treatments reported in the literature and to describe our treatment algorithm for HSFs. It was hypothesized that our treatment algorithm can solve the aforementioned problems of conventional MIPO for HSFs.

Patients and method

This retrospective, single-center study was conducted at a level 1 academic trauma center with institutional review board approval. Patients treated for HSFs with the medial approach were identified using ICD-10 codes. Inclusion criteria were: patients over 16 years of age; treated between November 2016 and February 2022; closed injury; follow-up time greater than or equal to 12 months. Exclusion criteria were: open or pathological fracture; pre-existing shoulder or elbow joint limitations; and additional injuries or diseases that may affect functional rehabilitation.

Twenty-one patients met the criteria, with demographic and fracture information summarized in Tables 1, 2, and detailed data provided in Table 3. All patients were treated with open reduction and internal fixation within 1–10 days (mean, 3 days) after their injuries. Fracture healing time was measured and the DASH score was recorded for evaluation during follow-up. This case series has been reported in line with the PROCESS criteria[9].

A treatment algorithm was derived from published evidence[10–14], taking into account patients' characteristics and special requirements. Different types of plates and combinations were used depending on the patient's situation (Fig. 4).

In 16 patients, a narrow 4.5 mm locking compression plate (Kanghui®, size 2.8 × 184 × 14.5 mm) was used. A 3.5 mm stainless steel LCP (Zimmer®, Universal Locking System) was used in three patients, one of them is a petite female who received a single plate, and the other two patients received a single plate combined with a 6 mm titanium rod (WALKMAN®, Orthobridge System). One patient received double 6 mm titanium rods. One patient received a single 6 mm titanium rod.

Surgical technique

The patient was positioned supine on an operating table with the affected limb abducted to 90°, resting on a radiolucent table. A C-arm radiograph device was positioned at the cranial side of the patient. Two assistants were required during the procedure. The plate was placed over the skin of the medial facet of the humerus under the guidance of the C-arm radiograph device to confirm the fracture site and the incision location. Two longitudinal 3 cm lines of incisions were made on the projection of the medial intermuscular septum from the humeral entepicondyle. The proximal approach was a part of the deltopectoral approach [Fig. 5]. The distal access was made between the biceps and triceps brachii [Fig. 6]. The plate was inserted along the medial aspect of the humerus from the distal to the proximal incision. Before reduction, the proximal fragment was fixed with the proximal half of the plate. The limb length, rotation, and alignment were restored through indirect reduction. The distal fragment was rotated so that the medial surface of the distal fragment was parallel to the plate surface. A lag screw was inserted into the second hole from the distal end to fix the distal fragment. Once the plate position was deemed acceptable with the C-arm radiographdevice, a locking screw was inserted into the distal hole next to the lag screw. For cases requiring additional fixation with a rod, another lateral incision of approximately 3 cm was made from the anterior surface of the lateral epicondyle to the proximal side. The rod was inserted proximally along the anterior surface of the humerus from the distal incision and could be used to maintain length. No external immobilization except a sling was usually used for pain management for 5 days post-surgery. Weight lifting restriction was routinely kept at a maximum of one kilogram for 6 weeks, which was carried out under the guidance of the patient's surgeon.

Table 2

Fracture Characteristics.

Variable	No
Closed injury	20
Open injury	1
Proximal metaphysis	4
Diaphysis-transverse	5
Oblique	3
Spiral	5
Segmental	1
Distal metaphysis	4

Results

All cases were followed for at least 12 months (range 12–67). There were no complications including postoperative infection, implant failure, or loosening. All fractures were consolidated and there were no neurovascular injuries caused by the procedure. One patient, who had a radial nerve palsy before surgery spontaneously recovered in the fifth month without exploration. The mean screw density was 0.43 (range 0.2–0.6). The mean radiological fracture union time was 15.76 weeks (range 8–40) and the mean DASH score was 3.29 (range 0–14.17) at the time of the last follow-up (Table 3).

Table 3

Cohort Data.

Case	Age (y)	Sex	Side	OTA/AO	Plate hole number	Screws used (proximal/ distal)	Screw Density	Follow-Up (months)	DASH score	Radiographic union (weeks)
1	38	M	L	A3.2	12	3/3	0.50	28	0	14
2	50	M	L	A3.2	10	3/3	0.60	32	0	18
3	45	F	L	A1.2	11	3/3	0.54	50	1.67	12
4	63	M	L	A2.2	13	4/3	0.53	67	2.5	17
5	24	M	R	B1.3	12	3/3	0.50	17	0	10
6	35	F	L	B1.2	16	3/4 Z	0.43	12	0.83	13
7	26	M	L	A3.2	R&P16	2R2/2P3 Z	0,25/0.31	17	0	16
8	26	M	L	C2.1	R&R	2R2/2R3	0.29/0.36	12	0	16
9	31	F	R	B1.3	R&P	3R4/2P2Z	0.31/0.25	45	4.17	22
10	75	F	R	B1.1	16	4/3 Z	0.44	23	14.17	12
11	45	M	L	A2.2	12	3/3	0.50	50	2.5	40
12	81	F	L	A1.2	14	3/3 Z	0.43	23	12.5	20
13	63	F	L	A1.2	14	4/4 Z	0.57	25	7.5	20
14	64	M	L	A2.2	12	3/3	0.50	25	2.5	12
15	48	F	L	B2.2	10	3/3	0.6	13	5.83	10
16	51	M	R	A1.1	14	3/3	0.43	13	2.5	15
17	22	M	L	A1.3	12	3/3	0.50	14	0.83	12
18	23	M	L	A3.2	10	2/2	0.40	12	0	12
19	25	M	L	B1.3	R	1/1	0.20	21	0	8
20	50	M	R	B1.1	12	3/3	0.50	13	6.67	20
21	36	M	L	A3.2	12	2/2	0.33	12	5	12

P, plate; R, rod; Z, Zimmer®Universal Locking System.

Discussion

In our study, all fractures healed without complications, including iatrogenic radial nerve palsy and infection. The functional outcome, with a mean DASH score of 3.29, was similar to that of two randomized controlled trials comparing surgery with functional bracing for HSFs[15,16]. In contrast to these trials, which reported higher nonunion rates and poorer DASH scores for functional bracing, our study found no cases of nonunion and a low DASH score.

Moreover, we observed that the medial approach we used in our study had a lower incidence of iatrogenic radial nerve palsy (0%) than that reported for minimally invasive plate osteosynthesis (2%) and open reduction and internal fixation (8.6%) in a recent systematic review and meta-analysis[8]. This meta-analysis also showed that MIPO was superior to ORIF in terms of union rate, union time, and incidence of nonunion, iatrogenic radial nerve palsy, and infection. The incidence of nonunion was 1.06% for MIPO and 6.05% for ORIF, while the incidence of infection was 0.71% for MIPO and 3.56% for ORIF[8].

We identified three questions that require clarification. Firstly, whether MIPO is suitable for treating transverse fractures of the humeral shaft, or what the indications of MIPO are for HSFs. It is widely believed that MIPO is best suited for treating fractures with low strain between fragments, and may not withstand the mechanical demands until the consolidation of transverse fractures[17]. However, it is evident that absolute stability is not a necessary condition for healing transverse HSFs, as they can be effectively treated with functional bracing (relative stability)[4,18]. In our study, all five cases involving transverse fractures were successfully fixed without complications. We believe that absolute stability is a necessary condition for plate survival and reducing strain in the fracture gap with short segment fixation, as simple fractures tend to produce local stress concentration and high strain in the fracture site. Without absolute stability, shorter fixation segments result in greater stress concentration at the site of the plate adjacent to the fracture. The results of our study suggest that medial minimally invasive techniques can be used for all types of closed HSFs. The proposed technique can immobilize the entire humerus at both ends. At the proximal end, screws can be placed into the humeral head utilizing part of the pectoralis major deltoid approach and special screw clips. At the distal end, screws can be placed into the medial and lateral condyles of the humerus using the double rod technique. Therefore, fractures in the entire humeral shaft area can be fixed by this technique, including multiple fractures of the humeral shaft adjacent to the humeral head and extra-articular distal humeral shaft fracture.

The second question pertains to the optimal stiffness of the implant for HSFs with MIPO, specifically the number of screws used per fragment. The mechanical environment of the fixation is crucial for successful healing, with an optimal balance between stability and flexibility[19]. Factors such as screw density, plate span width, rod diameter, and the number of plates or rods used can affect construct stiffness. In our study, Case 18, a 23-year-old male weighing 60 kg with a height of 160 cm, had a fracture fixed with a 10-hole plate construct using two screws per fragment Fig. 1. Although, the fracture eventually healed, there was no callus formation until the 7th week, suggesting that the construct may have been too rigid for this individual.

Additionally, the construct with three screws per fragment tended to result in little callus formation, particularly in smaller patients. This is due to the decreased working length resulting from the use of three locking screws, which leads to a significantly higher stiffness in the axial and torsional directions. Therefore, the authors suggest that two screws per fragment are generally sufficient for most Asian individuals and that the decision to use a third screw should be made on a case-by-case basis, taking into account the patient's weight-bearing needs and activity level,

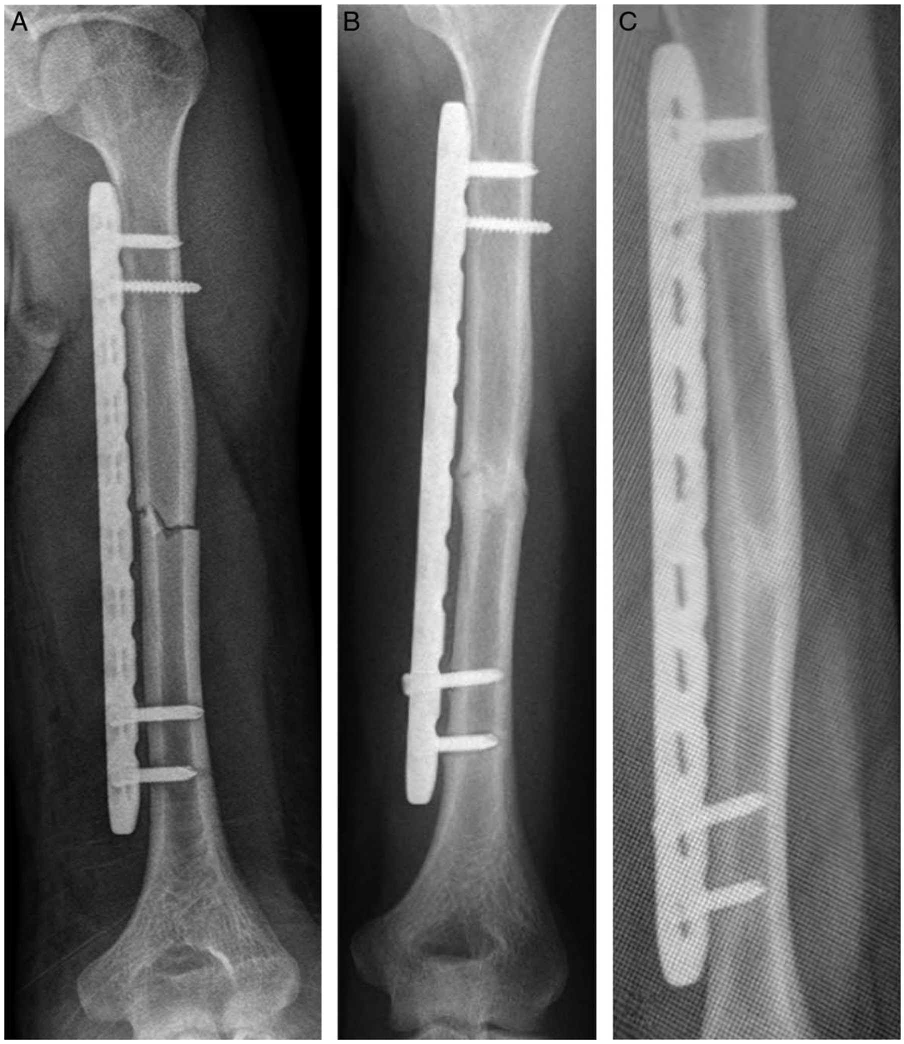

Figure 1. The construct with two screws per fragment is still stiffer for small patients for cellus formation. (A) X-Ray of a 23-year-old male with a height of 160 cm and weight of 60 kg at the day after surgery. (B) X-Ray at 32 weeks after surgery. (C) X-Ray at 1 year after surgery.

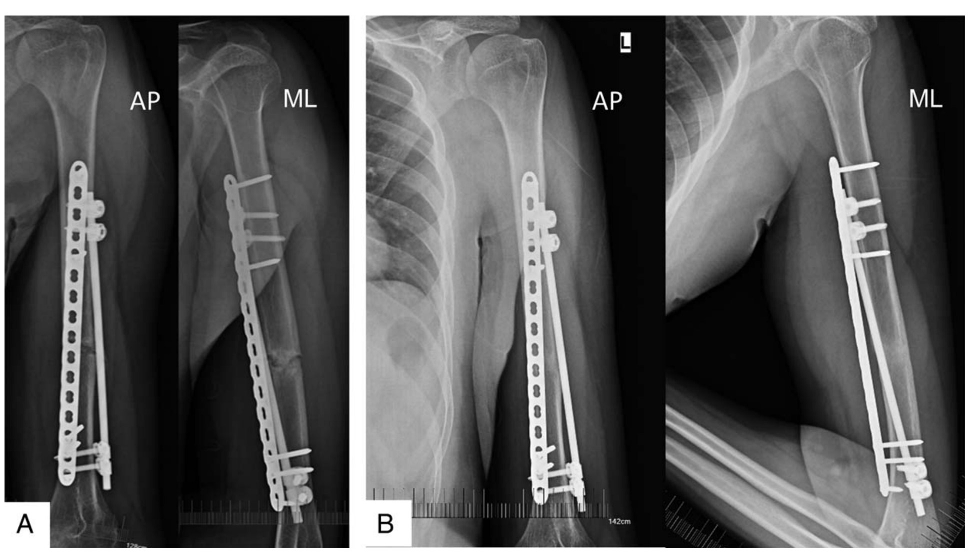

Figure 2. A plate combined with a rod could meet the need for an early and aggressive range of motion. (A) X-Ray at 6 months after surgery. (B) X-Ray at 18 months after surgery.

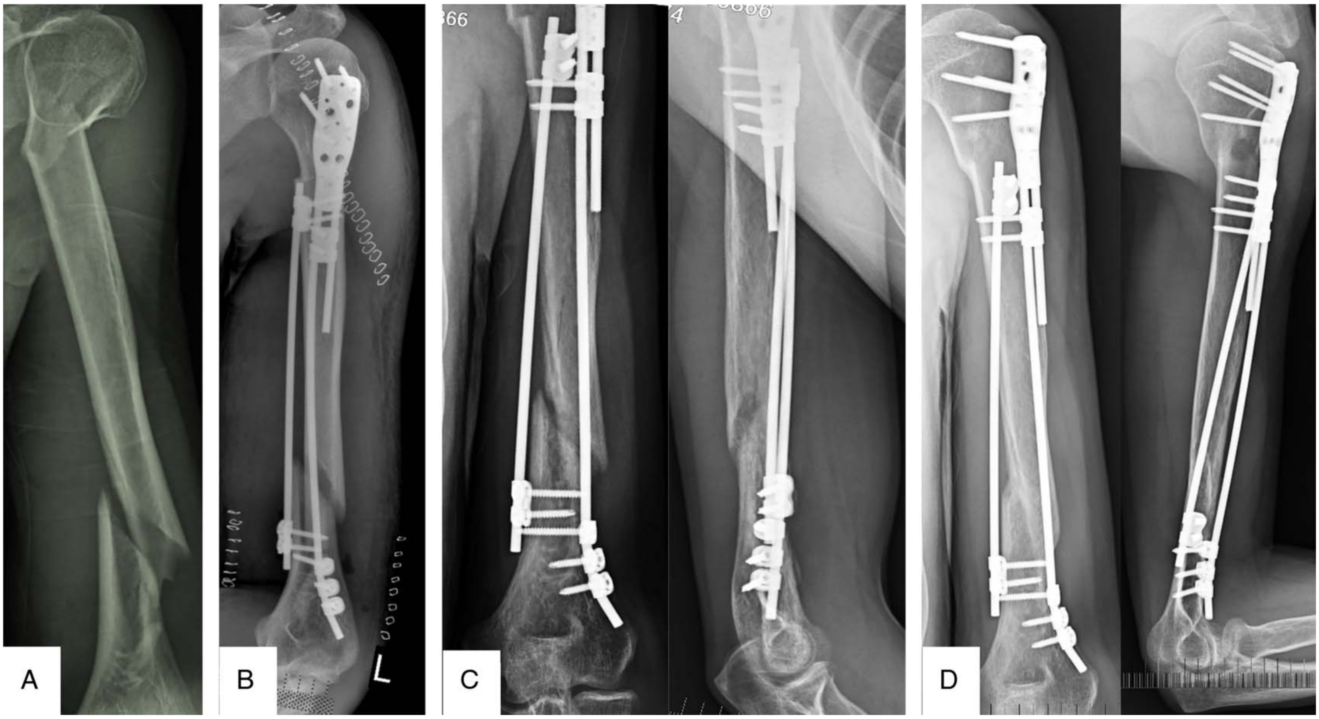

Figure 3. Multifragmentary HSFs are easy for medial minimally invasive technique. (A) X-Ray of preoperation. (B) X-Ray on the day after surgery. (C) X-Ray at 18 weeks. The fracture consolidated. (D) X-Ray at 18 months.

which may require the use of finite element analysis[20]. For instance, in Case 7, a 26-year-old man who weighs 105 kg and is 189 cm tall, suffered a humeral shaft fracture due to a traffic accident and also had a patella fracture, necessitating the use of the injured arm for daily activities. To avoid implant failure, the fracture was fixed medially with a plate and laterally with a rod. Although, the fracture achieved excellent reduction, there was no subperiosteal ossification until the fracture fully consolidated (Fig. 2A, B). This suggests that the fixation was too rigid to allow for callus formation and that the construct's strength was adequate for the patient's weight-bearing and activity needs.

Fixation of an extra-articular distal humeral shaft fracture is often difficult with a single DCP plate for surgeons can hardly get enough room for distal fixation with a conventional plate to have adequate purchase in the distal fragment, and achieving robust fixation in diaphyseal fracture of the humerus for immediate weight-bearing and high-intensity activity is more challenging. Many scholars have adopted the dual plate technique to solve these problems[10–14]. In our case series, two patients received a combination of a plate and a rod, and one patient received double rods. We give suggestions on the use of the supplemental titanium rod in the flowchart of the algorithm (Fig. 4). As an in-depth study on this issue is lacking, insufficient evidence is available.

The third question is how to achieve adequate rotational alignment reduction. Humeral rotation cannot be accurately determined intraoperatively even with adequate intraoperative images in AP, lateral, and oblique views. Several authors have proposed several methods for measuring the rotation of the humeral head during surgery, but they could only be used to avoid gross rotational malalignment[21–23]. In addition, the coronal and sagittal angulations can be fine-tuned after obtaining initial fixation with the distal and proximal screws that were not fully tightened. However, rotational malalignment cannot be corrected after the first two screws are inserted.

The medial minimally invasive technique has the advantage of using lag screws drilled perpendicular to the bone surface on the plate to reduce rotational and coronal angulation, as the medial surface of the humerus is perfectly flat. However, further research is necessary to develop more dependable methods for surgeons to achieve adequate rotational alignment.

Another advantage of the medial minimally invasive technique is that it allows for the use of longer distal screws and provides more fixation options for HSFs located near the fossa olecrani. Case 8 involved a 26-year-old male with an OTA/AO type 12-C2.1 multi-fragmentary fracture, which is difficult to fix using conventional methods due to the distal fracture's proximity to the fossa olecrani. However, it is easy to fix using the medial minimally invasive with two rods, and both fractures consolidated 8 weeks after surgery (Fig. 3A, B).

Despite its technical limitations, MIPO offers certain advantages over ORIF, such as reduced harm, shorter union time, and a lower incidence of the three major complications—nonunion, iatrogenic radial nerve palsy, and infection. It also offers advantages over nonoperative management, such as a higher union rate, shorter weight-bearing time, and greater cost-effectiveness[24].

The main limitations of this study are lacking a control group and the small sample size, and further research is needed to address additional questions such as the optimal screw density and plate span width for HSFs, as well as the nonunion rate of transverse HSFs with the proposed treatment algorithm in larger patient populations.

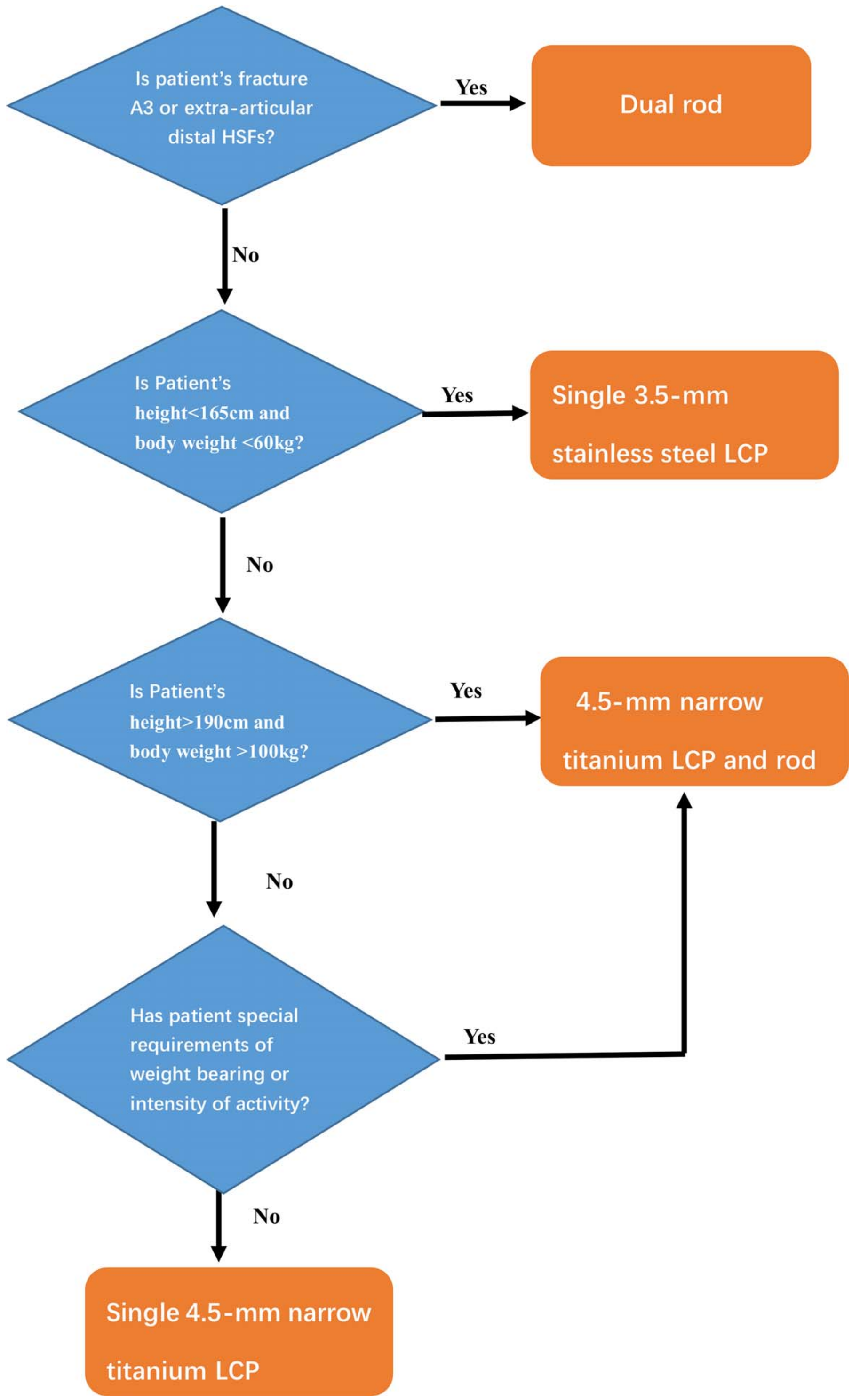

Figure 4. Flowchart of the algorithm.

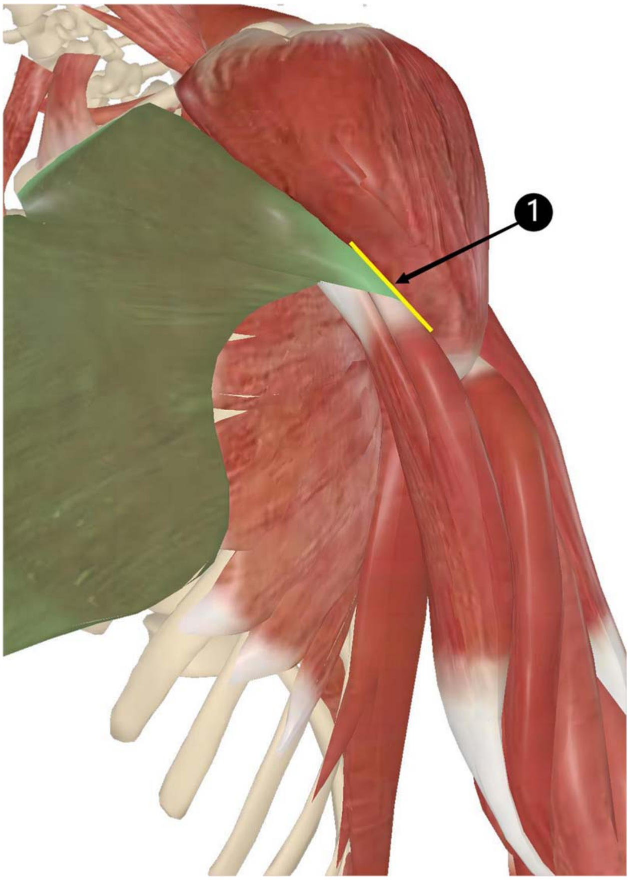

Figure 5. The proximal access. ① The proximal incision.

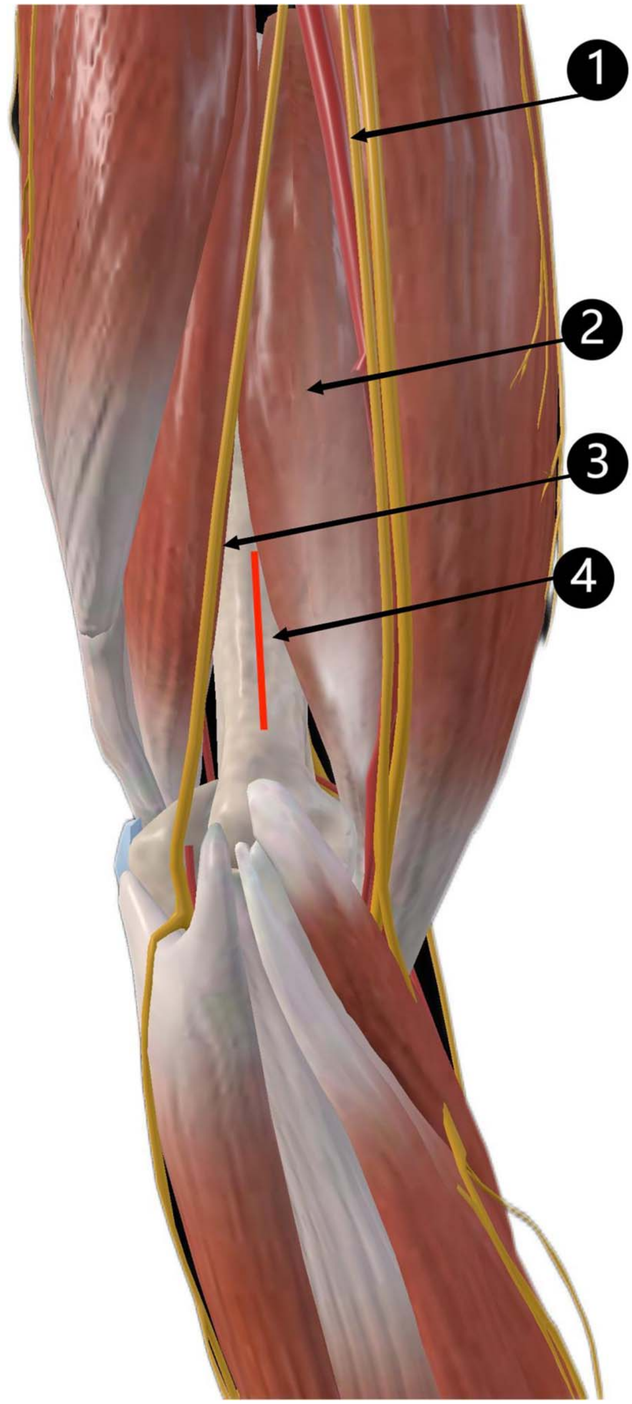

Figure 6. The distal access. ①The brachial artery and median nerve. ②The brachialis. ③The ulnar nerve. ④The distal incision.

Conclusion

The proposed algorithm is effective in addressing the challenges of iatrogenic nerve injury and extra-articular distal fixation of HSFs with conventional MIPO techniques.

Ethical approval

This study was exempted by the institutional ethics committee.

Consent

Informed consent was obtained from all individual participants included in the study.

Sources of funding

None.

Author contribution

D.L. performed all the surgeries and is the major contributor in development of the surgical technique, and was responsible for the concept of study, the assembly, analysis and interpretation of the data, and the drafting of the article; J.L. collected and analyzed the datasets of the study; H.Y. and Z.L. contributed to the writing of the article and was responsible for data and pictures collection; Y. Z. was the independent observer who performed the clinical and radiological assessment. All authors read and approved the final manuscript.

Conflicts of interest disclosure

No conflict of interest.

Research registration unique identifying number (UIN)

Not applicable.

Guarantor

The Guarantor is Da-peng Liu.

Data availability statement

The data and materials during the current study are available from the corresponding author on reasonable request.

Provenance and peer review

Not commissioned, externally peer reviewed.

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