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Treatment of distal third humeral shaft fractures with posterior minimally invasive plate osteosynthesis (MIPO) with segmental isolation of the radial nerve: minimum one-year follow-up

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A R T I C L E I N F O

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Humerus fracture
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Radial nerve
Humerus shaft fracture
Extra-articular distal humerus plate
Osteosynthesis

Level of evidence: Level IV; Retrospective Case Series

Background: Open reduction and internal fixation with plate is one of the most widely used treatments for distal third humeral shaft fractures. The purpose of this study was to report the outcomes of the treatment of distal third humeral shaft fractures with posterior minimally invasive plate osteosynthesis (MIPO) with segmental isolation of the radial nerve.

Methods: We performed an observational, retrospective, consecutive, monocentric, continuous multi-operator study. We reviewed 22 distal third humeral shaft fractures treated with posterior MIPO in our institution with an extra-articular distal humerus plate from 2018 to 2021. Inclusion was limited to functionally independent patients with displaced fractures involving the junction of the middle and distal thirds of the humerus and minimum 12-month follow-up for implant removal. We assessed clinical outcomes including range of motion; QuickDASH score; Mayo Elbow Performance Score; and Constant-Murley score.

Results: The average follow-up period of the sample was 31.7 ± 11.6 months (range, 15.7-51.3 months). The average elbow flexion and extension were 146.4° ± 7.3° (range, 120°-150°) and −0.7° ± 3.3° (range, −15° to 0°), respectively. The average shoulder anterior flexion, elevation, and abduction were 178.6° ± 3.6° (range, 170°-180°), 179.1° ± 2.9° (range, 170°-180°), and 140.9° ± 14.8° (range, 110°-160°), respectively. The average external rotation was 88.6° ± 6.4 (range, 65°-90°). The mean visual analog scale score for pain was 1.0 ± 1.6 (range, 0-5) and the mean Mayo Elbow Performance Score was 90.5 ± 9.9 (range, 70-100). The mean QuickDASH and Constant–Murley scores were 4.7 ± 6.8 (range, 0-20.5) and 95.5 ± 5.1 (range, 81-100), respectively. Two patients presented with relevant compromise of radial nerve motor function postoperatively (M3 and M2; the more compromised was preoperative injury). All patients recovered radial nerve neuropraxia within six weeks postoperatively. All fractures achieved union. The average anteroposterior and lateral axis were 175.0 ± 3.6 (168.0°-180.0°) and 177.5 ± 2.0 (173.0°-180.0°), respectively. No superficial or deep infection was reported. No cases of re-displacement of fracture, implant failure, or any other implant-related complication in follow-up were reported. No patient required plate withdrawal.

Conclusion: The results of this study demonstrate that the posterior MIPO technique is a reliable option for treating distal third shaft humeral fractures. The radial nerve must be identified and protected in all cases to prevent palsy.

Minimally invasive plate osteosynthesis (MIPO) has advantages over conventional techniques.[17] MIPO is a surgical technique that emphasizes minimal soft tissue dissection, indirect reduction techniques to restore anatomic alignment, and bridge plate fixation of metaphyseal and diaphyseal fractures.[17] This technique is

Clinical Research Ethical Committee of Instituto Traumatológico approved a patient registry, and all patients provided informed consent before participation.

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associated with improved soft tissue management, preservation of blood supply, and control of the periarticular fragments.[17] MIPO for humeral shaft fractures yields functional outcomes similar to those of open reduction and internal fixation with significantly less blood loss, shorter operative duration, and a lower incidence of nonunion, iatrogenic radial nerve palsy, and infection.[2,10,16] However, the MIPO technique has been more widely studied in fractures of the middle third of the humerus through the anterior approach.

In fractures involving the junction of the middle and distal thirds of the humerus, single column osteosynthesis with an extra-articular distal humerus plate (EADHP) using the triceps sparing posterolateral approach has gained popularity among surgeons with studies reporting excellent functional results and low complication rates.[1,11,14,18] This plate has a shape that is adapted to the posterior surface of the humerus, which in most cases presents an adequate fit and biomechanical characteristics that render it a reliable and safe alternative in fractures of the distal humeral shaft.[13,15]

A cadaveric study demonstrated the safety and feasibility of using an EADHP with the posterior MIPO technique.[8] The risk of radial nerve injury can be minimized by careful dissection in the proximal incision, considering that the nerve crossed the medial border of the posterior surface of the humerus at 31.7%-45.6% of the total humeral length ([HL] average, 10.4 cm; range, 8.01-13.2 cm). Gallucci et al described the technique and reported clinical results of posterior MIPO for distal third humeral shaft fractures with segmental isolation of the radial nerve using a narrow, 4.5/5.0 mm locking compression plate helicoidally bent to adapt to the posterior surface and distal aspect of the humerus.[4,5] A proximal incision was made in the posterior aspect of the arm, 10 cm distal to the posterolateral angle of the acromion (PLAA). Only one patient developed transient postoperative radial nerve palsy (4.8%).[4] Contreras et al confirmed that the radial nerve location was 100.2 ± 17.1 mm (36.6% HL) at the humerus medial border in relation to PLAA based on magnetic resonance imaging.[3]

Jitprapaikulsarn et al used MIPO via a posterior approach and EADHP fixation for 18 fractures. All fractures were united with only two cases of transient radial nerve palsy.[9] However, the available literature is of low quality and only refers to limited case series. Thus, the objective of this study was to assess the clinical and functional outcomes of distal third humeral shaft fractures treated with posterior MIPO with segmental isolation of the radial nerve and a minimum one-year follow-up.

Materials and methods

Patient selection and study design

Our study was performed following the Strengthening the Results of Observational Studies in Epidemiology statement for cohort studies and the Declaration of Helsinki. Our ethical committee approved a patient registry, and all patients provided informed consent before participation. This study was an observational, retrospective, consecutive, monocentric, continuous multioperator study. We reviewed 22 consecutive distal third humeral shaft fractures treated in our institution using posterior MIPO with segmental isolation of the radial nerve using a titanium EADHP (DuPuy Synthes, Raynham, MA, USA) from December 2018 through November 2021 by the Shoulder and Elbow Unit of our institution.

Inclusion was limited to several parameters: (1) closed, isolated, unilateral, displaced/angulated/shortened fractures involving the junction of the middle and distal thirds of the humerus that were suitable for single column osteosynthesis with an EADHP; (2) an indication of relative stability according to Arbeitsgemeinschaft für Osteosynthesefragen (AO) principles in functionally independent patients at the time of injury (AO/Orthopaedic Trauma Association 12A1(c), 12B2(c), 12B3(c), 12C2(k), and 12C3(k)) (Fig. 1); and (3) at least one year of follow-up for implant removal. The EADHP was used by our team for the most distal third humeral shaft fractures treated during the study period.

Table I
Sample data.

Demographic characteristic	
Age, mean ± SD, years	29.4 ± 11.1
Sex	
Female, n	13
Male, n	9
Follow-up, mean ± SD, months	31.7 ± 11.6
Injury Mechanism	
Fall to the level, n	13
Motorcycle accident, n	8
Armwrestling, n	1

SD, standard deviation.

We excluded patients with other types of lesions/fractures: (1) symptomatic degenerative pathology of the ipsilateral upper extremity;(2) concurrent traumatic lesions of the ipsilateral upper extremity; (3) middle third or supracondylar humerus fractures; (4) fracture with articular extension; (5) transverse and short oblique fractures; and (6) concurrent additional injuries to structures associated with elbow instability to minimize possible confounding injuries, and thus to focus on the humerus fracture itself. No patients were excluded from the analysis because they all attended the postoperative control sessions while one patient was excluded for an open fracture.

Demographic data

Thirteen patients were women, and nine were men (n = 22). Their average age at the time of surgery was 29.4 years (range, 16-53 years). The most frequent mechanism of injury was a fall onto an outstretched hand (59%) as shown in Table I.

Surgical technique

Our surgical technique was an adaptation of the Gallucćs technique, but we used an EADHP plate.[4,5] Following induction of regional and general anesthesia, the patient is positioned prone on the operating table with the affected extremity over an arm support and with the shoulder abducted and the elbow flexed over a well-padded armrest allowing elbow flexion >90 degrees (Fig. 2). In this position, by applying axial traction and stabilizing it with elbow flexion against the armrest, we achieved an adequate reduction, which is easy to maintain throughout the procedure. The upper extremity was prepared and draped in standard orthopedic fashion with special interest leaving the acromion free for identification and demarcation of anatomical references. Under fluoroscopy, the proximal and distal limits of the fracture site were demarcated on the skin. If the fracture site was compromised with any of the incisions, the use of the MIPO technique was ruled out and a triceps sparing posterolateral approach was performed.

The proximal incision of approximately 5 cm long was made in the posterior aspect of the arm, 10 cm distal to the PLAA (Fig. 3, *A* and *B*). The location of the proximal window was always confirmed in relation to 36.6% of the HL (defined as the straight-line distance between PLAA and the lateral epicondyle).[3] This measurement was made using a suture to directly measure the HL, and then it was quantified with a surgical ruler. Dissection was then performed between the long portion of the triceps and the posterior border of the deltoid muscle down to the humerus. The interval between the

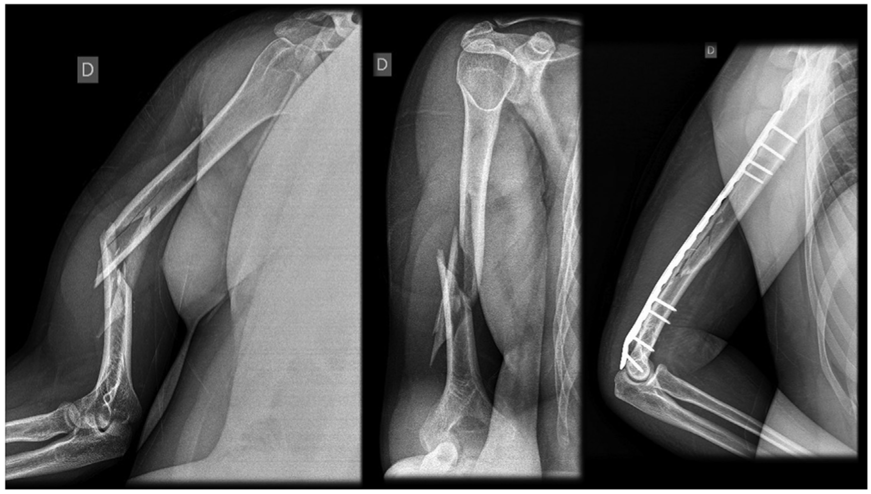

Figure 1 Fracture involving the junction of the Middle and distal thirds of the humerus. This case is an example of a closed, isolated, unilateral, displaced, angulated and comminuted fracture involving the junction of the Middle and distal thirds of the humerus that is suitable for single column osteosynthesis with an EADHP; AO/OTA 12C3(k). *EADHP*, extra-articular distal humerus plate; *AO/OTA*, Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association.

Figure 2 Prone position. Following induction of regional and general anesthesia, the patient is positioned prone on the operating table with the affected extremity over an arm support and with the shoulder abducted and the elbow flexed over a well-padded armrest allowing elbow flexion >90 degrees. In this position, by applying axial traction and stabilizing it with elbow flexion against the armrest, we achieved an adequate reduction, which is easy to maintain throughout the procedure.

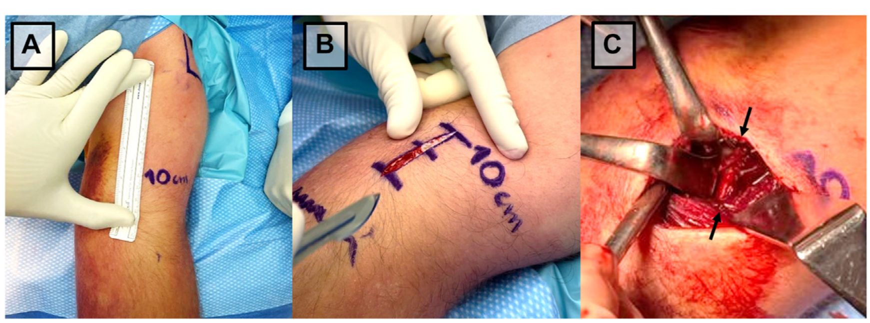

Figure 3 Segmental isolation of the radial nerve. (**A** and **B**) A proximal incision of approximately 5 cm long is made in the posterior aspect of the arm, 10 cm distal to the posterolateral angle of the acromion. C. The interval between the long and lateral heads of the triceps is developed to expose the radial nerve, which must be meticulously protected.

long and lateral heads of the triceps was developed to expose the radial nerve, which must be meticulously protected (Fig. 3, *C*). The nerve must be released proximally and distally enough to allow the plate to slide deep to the nerve using atraumatic dissection. The distal incision is made on the posterior aspect of the arm over the distal humerus lateral column for the same length of the proximal incision (Fig. 4, *A* and *B*). The triceps aponeurosis is opened at the lateral border and carefully dissected medially to preserve adequate coverage for the distal part of the plate (Fig. 4, *C* and *D*).

A 3.5 mm titanium EADHP (DePuy Synthes, Raynham, MA, USA) was slightly bent to reproduce the anterior curvature, posterior surface, and distal aspect of the humerus (Fig. 5). The plate must be located in the lateral column between the olecranon fossa and the lateral border of the bone. The length of the plate depends on the type of fracture, but it is usually one or two holes longer than the one used in the conventional open plating technique. The most frequently used plates are those with 10 and 12 holes. The fracture is manually reduced in an indirect way keeping traction on the arm to

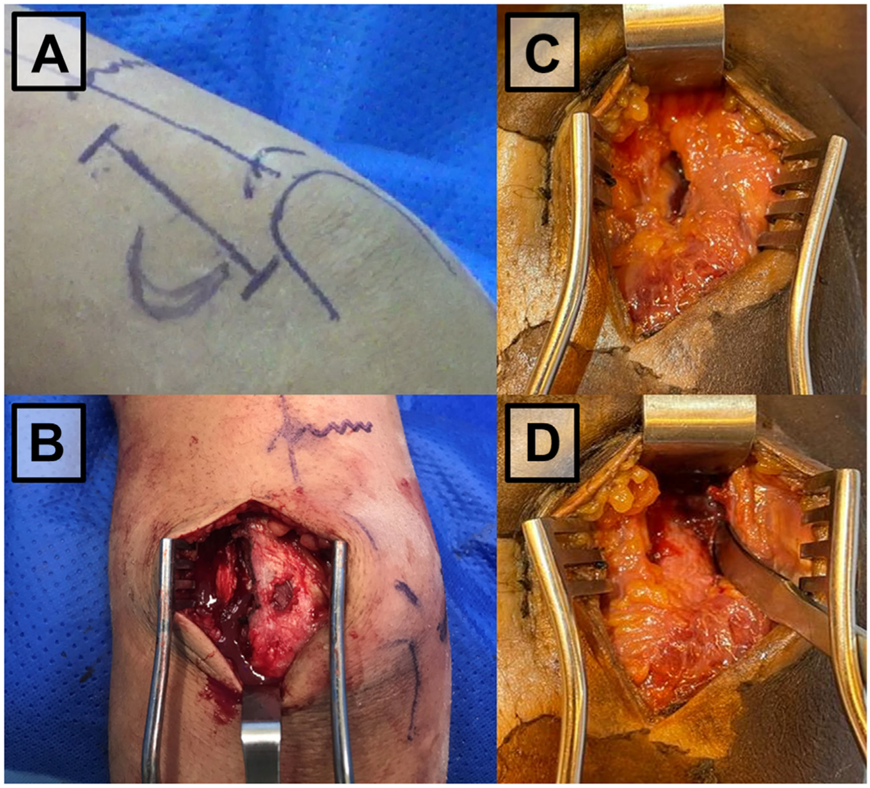

Figure 4 Distal incision. (**A** and **B**) The distal incision is made on the posterior aspect of the arm over the distal humerus lateral column for the same length of the proximal incision. (**C** and **D**) The triceps aponeurosis is opened at the lateral border and carefully dissected medially to preserve adequate coverage for the distal part of the plate.

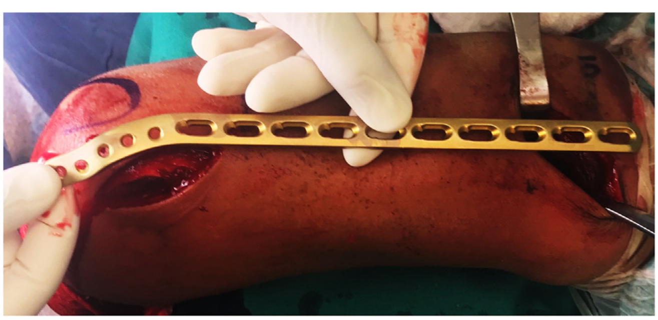

Figure 5 Extra-articular distal humerus plate. A 3.5 mm titanium extra-articular distal humerus plate (DePuy Synthes, Raynham, MA, USA) is slightly bent to reproduce the anterior curvature, posterior surface, and distal aspect of the humerus.

prevent the fragments from shortening. Rotational reduction is obtained though elbow flexion at armrest. Before sliding the plate, the extraperiosteal tunnel is prepared with a spinal Cobb elevator. The plate is inserted along the posterior aspect of the humerus from distal to proximal using a locking compression plate Drill Sleeve distally for better grabbing. The plate must be slid just over the bone to be located deep in the nerve. Care should be taken to avoid radial nerve injury. Carefully, digital palpation of the nerve can be done, and a gentle hook maneuver can be performed in which the plate slide under the finger to ensure neurological protection throughout the procedure. Before placing any screws, we performed a visual inspection of the radial nerve over the plate as a safety measure. We placed a proximal locking compression plate Drill Sleeve in the hole closest to the radial nerve to identify it during screw placement and to manipulate the plate proximally. The distal end of the plate was positioned lateral to the olecranon fossa over the lateral column distally enough to match the anterior curvature of the distal humerus with the shape of the plate.

When the length, rotation, and axis (functional reduction) of the humerus is approximately restored, and the plate is in the correct position, the proximal and distal portions of the plate are then temporarily fixed to the distal and proximal main fragments by putting the locking compression plate screw drills though the sleeve guides for initial fixation (Fig. 6, *A*). We always perform a radioscopic confirmation prior to fixation. If significant comminution or displacement of the fragments difficult to maintain reduced with traction alone, before placing the screws, extrinsic compression can be generated by placing an elastic bandage between the incisions before putting the screws (Fig. 6, *B*).

The first screw was a 3.5 mm cortical type that was inserted into the most proximal hole of the distal portion of the plate to fit it against the lateral column. Thereafter, a 3.5 mm cortical screw was placed in one of the three or more proximal holes of the plate at the proximal incision to pull the bone to reduce the gap between the humerus and the plate (Fig. 6, *C*). After the reduction was secured with two cortical screws and two drills, the alignment was confirmed in the anteroposterior view with radioscope and the rotation of the injured extremity was verified intraoperatively by assessing internal and external rotations, and then comparing these measurements to those of the unaffected contralateral arm, as recorded preoperatively. Once adequate plate positioning was verified, two more locking proximal and three distal screws were placed (Fig. 6, *D*). In type B (AO Classification) fractures, the third fragment was left untouched. Once the procedure was finished, the alignment of the fragments is then checked again with the C-arm, especially to confirm that no screw has penetrated the olecranon fossa. In our study, a controlled hemostasia was performed, and the incisions were closed (Fig. 6). This technique is available in VuMedi (https://www.vumedi.com/video/posterior-mipo-for-humerus-dia

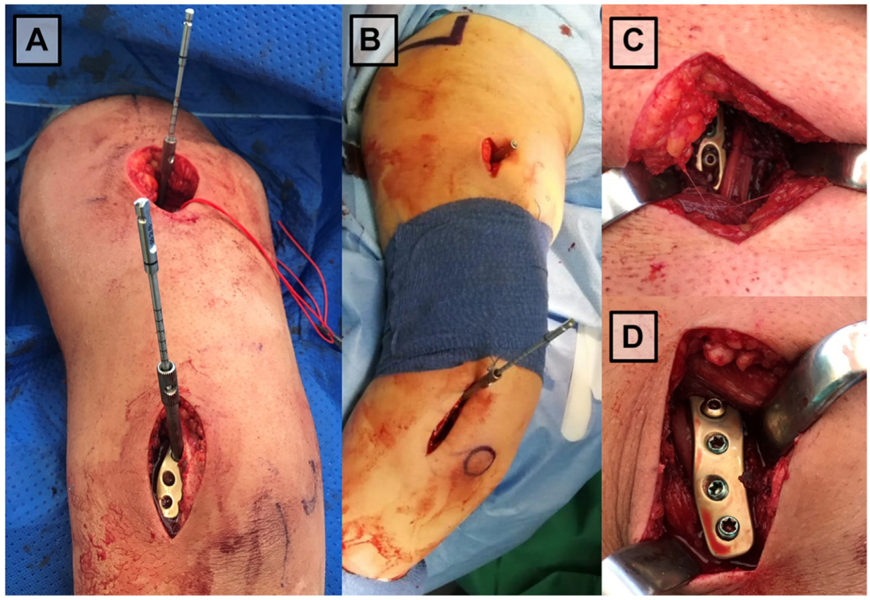

Figure 6 Functional reduction and plate fixation. (**A**) When the length, rotation, and axis of the humerus is approximately restored, and the plate is in the correct position, the proximal and distal portions of the plate are then temporarily fixed to the distal and proximal main fragments by putting the locking compression plate screw drills though the sleeve guides. (**B**) If significant comminution or displacement of the fragments difficult to maintain reduced with traction alone, before placing the screws, extrinsic compression can be generated by placing an elastic bandage between the incisions before putting the screws. (**C**) A 3.5 mm cortical screw is placed in one of the three or more proximal holes of the plate at the proximal incision to pull the bone to reduce the gap between the humerus and the plate. Once adequate plate positioning is verified, two more locking proximal are placed. (**D**) The first screw is a 3.5 mm cortical type that is inserted into the most proximal hole of the distal portion of the plate to fit it against the lateral column. Then, three distal locking screws are placed.

physeal-fractures-with-extra-articular-distal-humeral-anatomical-plate/; VuMedi, Oakland, CA, USA).

Postoperatively, patients were immobilized in a sling for two weeks. All patients were allowed to start active and passive movements immediately after surgery but were limited to non-weight-bearing activities and required to avoid external rotation movements for the first six weeks. More active exercises could be started when the callus appears. Therapy was not routinely prescribed. The same therapy protocol was applied to all patients by our institution's therapy team.

Clinical evaluation

Electronic medical records and functional evaluations were reviewed for demographic data, physical examination findings, and radiographic data. Complications, including wound dehiscence, infection, nonunion, neurovascular injury, stiffness, hardware removal, and repeat surgeries, were recorded. Relevant neuropraxia was defined as motor impairment M3 or higher, independent of the presence of sensory alterations.

Twenty-two patients were assessed at a minimum of six-months follow-up for subjective functional outcomes. The range of shoulder and elbow motion was checked with goniometer, and the degree of pain was evaluated with a visual analog scale score from 0 to 10. Overall functional status was evaluated using the Constant–Murley score, Mayo Elbow Performance Score, and the Quick Disabilities of the Arm, Shoulder, and Hand score (Quick-DASH). Of the 22 patients included in the study, no patient missed the functional evaluation. The presence of implant removal was evaluated after one year of follow-up in the entire sample.

Radiologic evaluation

Bony union, implant failure, loss of reduction, and anatomical measurements were evaluated retrospectively based on the available postoperative follow-up radiographs and medical records (Fig. 7). All radiographs were obtained using a digital imaging system (DigiRAD-FP [ST-5000C]; Digirad, Gyeonggi-do, Korea). Commercially available imaging software (Vue PACS; Carestream, Rochester, NY, USA) was used to enlarge images and conduct measurements. Two surgeons, specialized in the care of shoulder and elbow disorders, examined all radiographs, separately. The radiographs were reviewed to determine the adequacy of reduction (anteroposterior and lateral alignment), loss of reduction, hardware failure, progression of bony union (delayed union or nonunion was evaluated), and for the development of heterotopic ossification (including bony spurs or loose bodies). Fracture union was defined as more than three regions of bone bridging the lateral, medial, posterior, and anterior cortical aspects of the humeral diaphysis, which could be seen on anteroposterior and lateral projections. In case of doubt, a computed tomography (CT) scan was used to assess bone consolidation.

Statistical analysis

Results are presented with averages and standard deviation or percentages as appropriate.

Results

Clinical results

We reviewed 22 consecutive patients treated with a posterior MIPO with segmental isolation of the radial nerve and an EADHP. Surgical duration was 71.8 ± 17.6 (range, 46-110 minutes), and the average follow-up period of the sample was 31.7 ± 11.6 months (range, 15.7-51.3 months).

The average elbow flexion, extension, and flexion–extension arc were 146.4° ± 7.3° (range, 120°-150°), −0.7° ± 3.3° (range, −15° to 0°), and 145.2° ± 7.5° (range, 120°-150°), respectively. The mean

Figure 7 Bone union. Fracture union was defined as more than three regions of bone bridging the lateral, medial, posterior, and anterior cortical aspects of the humeral diaphysis, which could be seen on anteroposterior and lateral projections. In case of doubt, a computed tomography (CT) scan was used to assess bone consolidation.

pronation and supination were 89.8° ± 1.1° (range, 85°-90°) and 89.5° ± 1.5° (range, 85°-90°), respectively.

The average shoulder anterior flexion, elevation, and abduction were 178.6° ± 3.6° (range, 170°-180°), 179.1° ± 2.9° (range, 170°-180°), and 140.9° ± 14.8° (range, 110°-160°), respectively. The mean extension was 45.9° ± 13.7° (range, 10°-60°). The average external rotation was 88.6° ± 6.4 (range, 65°-90°). Most of the sample (86.4%) could reach with the end of the thumb to T7 (interscapular) for clinical internal rotation evaluation.

The mean visual analog scale score for pain was 1.0 ± 1.6 (range, 0-5) and the mean Mayo Elbow Performance Score was 90.5 ± 9.9 (range, 70-100) with 90.9% good and excellent results. The mean QuickDASH and Constant–Murley scores were 4.7 ± 6.8 (range, 0-20.5) and 95.5 ± 5.1 (range, 81-100), respectively.

In relation to the radial nerve, three patients were diagnosed with preoperative radial neuropraxia (Table II). Postoperatively, just two patients presented with relevant compromise of radial nerve motor function (M3 and M2), and the more compromised was one of the patients with the preoperative radial nerve injury. Another two patients reported an objective diminished wrist extension (M4). Five patients reported sensitive symptoms (hypoesthesia, paresthesia) in three of the muscle symptoms group. Nonetheless, all patients recovered radial nerve neuropraxia within six weeks postoperatively.

No superficial or deep infection was reported. No cases of re-displacement of fracture, implant failure, or any other implant-related complication in follow-up were reported. No patient required plate withdrawal.

Radiological results

All fractures achieved union, and no nonunion was seen; there was agreement between the observers in all cases. The average anteroposterior (procurvatum deformity) and lateral (varus deformity) axes were 175.0 ± 3.6 (168.0°-180.0°) and 177.5 ± 2.0 (173.0°-180.0°), respectively.

Discussion

The main finding of our study suggests that the clinical and functional results of distal third humeral shaft fractures treated with posterior MIPO with segmental isolation of the radial nerve are excellent and are associated with a high bone union rate and low rate of complications, establishing this procedure a possible alternative to the classical treatment of these type of fractures.

The indication for this technique includes displaced fractures involving the junction of the middle and distal thirds of the humerus that are suitable for single column osteosynthesis with an EADHP and with an indication of relative stability according to AO principles. This group of patients previously were already being treated with an EADHP plate, so we only modified the type of approach by improving soft tissue management and preserving blood supply to obtain high rates of bone union and lower incidences of infections and by performing a focused and delimited dissection of the radial nerve to reduce iatrogenic radial nerve palsy.[2,10,16]

For our group, the ideal fracture to be treated with a posterior MIPO plate includes fractures that are distal to the radial nerve at its exit from the posterior cortex of the humerus as long as the fracture hematoma is not violated by dissecting the radial nerve; therefore, fractures distal to 53.6% of the HL in relation to the PLAA will be ideal for treatment with this technique.[3]

The clinical and functional results of our series are excellent. Elbow and shoulder range-of-motion is practically unaffected by posterior MIPO and is probably related to the facts that this surgical technique respects both joints and leaves them intact unlike intramedullary nails. The elbow and shoulder scores are at the upper limit of the scales used. The same occurs with a practically non-existent disability and is probably related to the low compromise of soft tissues, respect for both joints, and other proven benefits of the MIPO technique. These results are similar to the data published by Gallucci et al and Jitprapaikulsarn et al.[4,9]

Regarding the radial nerve, when excluding patients with preexisting radial nerve injuries and focusing on motor impairment as a meaningful indicator of neuropraxia, while disregarding temporary sensory disruptions, our case series demonstrated a postoperative neuropraxia rate of 14%. Furthermore, if we consider patients with M3 or more motor impairment, the proportion of patients drops to 4.8%. Using the criteria for "radial nerve palsy" (defined as M2 or higher compromise), only a single patient exhibited this condition prior to the operative treatment. These results are excellent when comparing similar series with open reduction techniques, considering that the definitions of radial nerve palsy are variable and, in general, less strict and less rigorous. Gupta et al[7] reported 8% and 3% of preoperatively and postoperatively radial nerve palsy, respectively; nonetheless, the definition is not explained. Ghega et al[6] reported two patients (6.5%) with radial nerve palsy postoperatively with EADHP using the triceps-sparing posterolateral approach.

The location of the radial nerve in relation to the humerus is related to the HL and can be used to predictably define the safe zones to avoid nerve injury in the proximal incision of posterior MIPO for humerus fractures. This process allows a direct search for the radial nerve in the area that crosses the posterior aspect of the humerus,

Table II
Preoperative and postoperative radial nerve neuropraxia.

Patient	Preoperative neuropraxia	Sensitive	Motor	Postoperative neuropraxia	Sensitive	Motor
1	No	10/10	M5	No	10/10	M5
2	No	10/10	M5	No	10/10	M5
3	No	10/10	M5	**Yes**	**8/10**	**M4**
4	**Yes**	10/10	**M5**	No	10/10	M5
5	No	10/10	M5	**Yes**	**8/10**	**M5**
6	No	10/10	M5	No	10/10	M5
7	No	10/10	M5	**Yes**	**7/10**	**M5**
8	No	10/10	M5	**Yes**	**7/10**	**M4**
9	**Yes**	10/10	**M3**	No	10/10	M5
10	No	10/10	M5	No	10/10	M5
11	No	10/10	M5	No	10/10	M5
12	**Yes**	10/10	**M2**	**Yes**	**10/10**	**M2**
13	No	10/10	M5	No	10/10	M5
14	No	10/10	M5	No	10/10	M5
15	No	10/10	M5	No	10/10	M5
16	No	10/10	M5	No	10/10	M5
17	No	10/10	M5	No	10/10	M5
18	No	10/10	M5	No	10/10	M5
19	No	10/10	M5	No	10/10	M5
20	No	10/10	M5	No	10/10	M5
21	No	10/10	M5	No	10/10	M5
22	No	10/10	M5	**Yes**	**4/10**	**M3**

Bold indicates any neurological sensory and/or motor alteration.
Muscle strength evaluation (Medical Research Council Manual Muscle Testing scale): M0 = No muscle activation; M1 = Trace muscle activation, such as a twitch, without achieving full range of motion; M2 = Muscle activation with gravity eliminated, achieving full range of motion; M3 = Muscle activation against gravity, full range of motion; M4 = Muscle activation against some resistance, full range of motion; M5 = Muscle activation against examiner's full resistance, full range of motion.

and a careful, focused, and limited dissection preserves the epineurial vessels and theoretically reduces neuropraxia.[12] In open reduction techniques, a triceps sparing posterolateral approach is used for dissection. Neurolysis of the radial nerve is extensive and difficult to approach proximally and requires large approaches or causes discomfort for surgeons in managing this area. The posterior MIPO technique delimits the dissection to the area in which the plate will slide under the radial nerve, while the traditional technique requires practically complete neurolysis of the nerve, associated with a higher rate of postoperative neuropraxia. In our series, all patients presented recovery from neuropraxia within six weeks. None required repeat surgery or nerve exploration.

The bone union rate and the measurements about the functional reduction of the humerus were excellent. Probably, this process is associated with the indication for this technique in fractures that require relative stability for their consolidation and respect for the fracture hematoma throughout the application of the surgical technique. These results are similar to the data published by Gallucci et al and Jitprapaikulsarn et al[4,9] Gupta et al[7] reported that 6% of patients developed nonunion for open technique.

In relation to functional reduction, it is important to mention that our results were excellent, but those patients with an evolution period exceeding 10 days are excluded for MIPO since the reduction becomes more complex. A relevant topic to mention is humeral rotation. It is a complex issue to evaluate intraoperatively, which is even more difficult in the prone position. Currently, no reliable method and expert recommendations are available to evaluate the rotations of the contralateral limb and confirm them once reduction and fixation have been performed. In this series, we had no postoperative problems related to rotation.

In relation to infection, in our series we did not have cases of superficial or deep infection, similar to results reported in other publications concerning the MIPO technique.[4,9] Páramo-Díaz et al[14] reported an 8.7% of superficial infection for the open approach.

This study has several limitations. In this retrospective and nonrandomized study, patient selection may be biased by the preference of treating surgeons; however, most fractures involving the junction of the middle and distal thirds of the humerus for single column osteosynthesis with an EADHP during the study period were treated with the MIPO technique. Regarding the surgical technique, the fact that several surgeons were included produced technical variability in a few cases. Follow-up was adequate, and a response rate of 100% to functional scores was obtained, which minimized response bias. In addition, the minimum follow-up for implant removal was one year. Finally, we studied a relatively small number of patients, which may have affected the occurrence of some complications as infections and nonunion.

Conclusion

The results of this study demonstrate that the posterior MIPO technique is a reliable option for treating distal third shaft humeral fractures. The radial nerve must be identified and protected in all cases to prevent palsy.

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