

Antero-lateral minimally invasive plate osteosynthesis (MIPO) with the radial nerve exploration for extra-articular distal-third diaphyseal fractures of the humerus

Wei Zhao¹ · Wei Qu¹ · Chongyang Fu¹ · Huajun Jiang¹ · Sida Liu¹ · Chao Cheng¹

Received: 16 February 2017 / Accepted: 11 May 2017 / Published online: 2 June 2017
© SICOT aisbl 2017

Abstract

Introduction Traditional open reduction and internal fixation (ORIF) of extra-articular distal humerus fractures has a risk of iatrogenic radial nerve injury, extensive soft tissue stripping, and long incision scar. We performed an antero-lateral minimally invasive plate osteosynthesis (MIPO) technique with the radial nerve exploration for distal-third diaphyseal fractures of the humerus and evaluated clinical and radiographic outcomes through this respective study.

Methods From April 2010 to June 2016, 28 cases of extra-articular distal-third diaphyseal fractures were treated with an antero-lateral MIPO procedure. Patient demographics, Disabilities of the Arm, Shoulder and Hand (DASH) Score, Mayo Elbow Performance (MEP) Score, elbow range of motion, scars and post-operative complications were recorded and analyzed.

Results All fractures were united with a mean time of 3.5 months. One patient exhibited delayed union (3.6%). The mean DASH Score was 6.6, and all patients had excellent or good MEP Score values. The average scar length was 6.8 cm, and the shortest was 4.5 cm.

Conclusions The MIPO technique via an antero-lateral approach for extra-articular distal-third diaphyseal fractures of the humerus results in satisfactory clinical outcomes.

Level of evidence Level IV, case series, treatment study.

Keywords Humerus fracture · Extra-articular fracture · Anterior-lateral plate · Radial nerve · MIPO

Introduction

Extra-articular distal-third fractures comprise 16% of humerus diaphyseal fractures [1], for which the treatment has some challenges, with ongoing debate. Non-operative treatment with a functional brace has a high rate of union and good function [2]. However, the disadvantages appear to be unavoidable and include a long immobilization time, malunion due to difficulty in controlling fracture alignment, elbow stiffness, and possible radial nerve injury during closed reduction [2, 3]. To restore alignment and achieve stable fixation for early elbow range of motion (ROM), some authors advocate managing these fractures surgically with open reduction and internal fixation (ORIF) [4, 5]. Posterior and lateral surgical approaches are more often used, though there is an associated risk of iatrogenic radial nerve injury due to the manipulation of nerve, extensive soft tissue stripping, and long incision scar. In recent years, minimally invasive plate osteosynthesis (MIPO) has gained popularity with satisfactory clinical outcomes in the treatment of middle diaphyseal humerus fractures [6, 7]. Regardless, it is not considered safe for distal third humeral fractures without the radial nerve exploration. Therefore, we performed an antero-lateral MIPO technique with the radial nerve exploration using a 3.5-mm universal locking system (ULS, Zimmer, Warsaw, Indiana, USA) for distal-third diaphyseal fractures of the humerus. The purpose of this retrospective study was to examine the clinical outcomes of this MIPO technique based on clinical and radiologic records.

Materials and methods

Our retrospective study was approved by the Institutional Review Board. From April 2010 and June 2016, 78 cases of

✉ Wei Qu
weiq9999@hotmail.com

¹ Department of Orthopaedics, The First Affiliated Hospital of Dalian Medical University, 222 Zhongshan Street, Dalian, Liaoning 116011, China

distal-third diaphyseal fractures of the humerus were treated in our department. Of these, 28 were treated with an anterolateral MIPO procedure using a 3.5-mm ULS. The inclusion criteria were: (1) age \geq 18 years, (2) closed fracture or grade I or II open fracture, (3) failure of closed reduction or intolerance to the long time immobilization. Pathologic fractures, grade III open fractures, age < 18 years and patients treated with non-operation or ORIF were excluded.

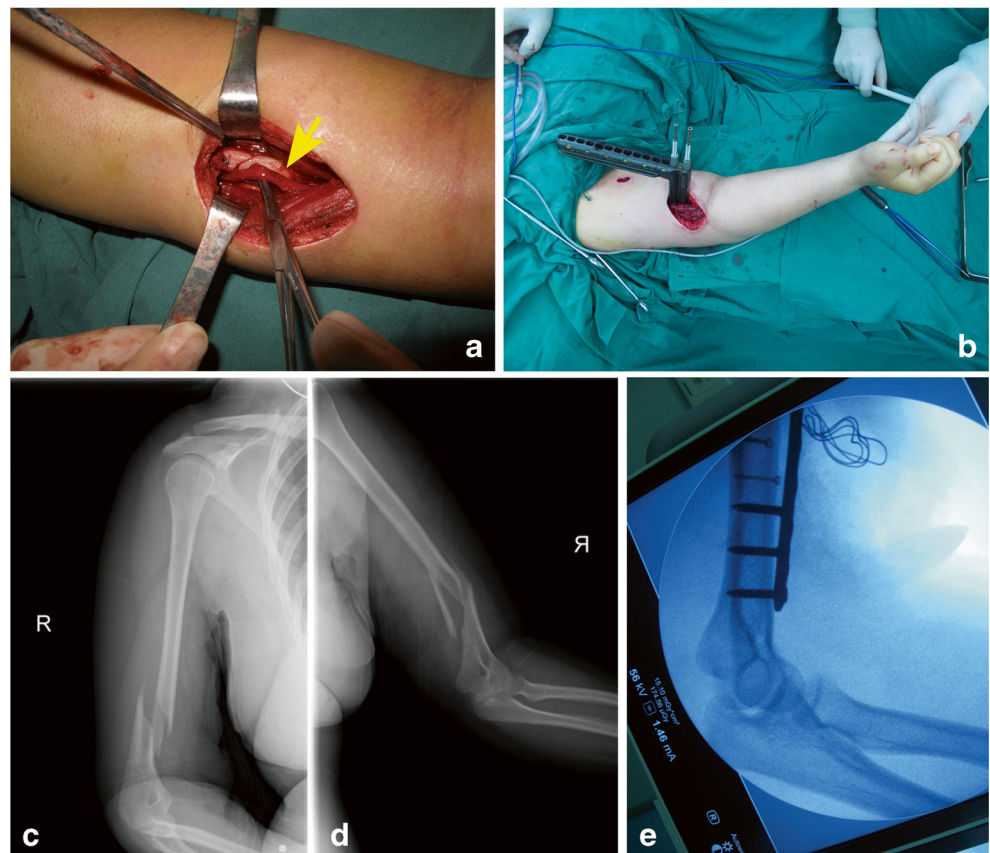
The patient demographics recorded included sex, age, side, injury cause, and complications. The fracture pattern was determined according to AO Foundation and Orthopedic Trauma Association (AO/OTA) classification. Intra-operative records were reviewed with regard to the operation time and distal screw number. During the follow-up period, Disabilities of the Arm, Shoulder, and Hand (DASH) Score, Mayo Elbow Performance (MEP) Score, elbow ROM, scars and post-operative complications (iatrogenic radial nerve injury, nonunion, delay union, infection, implant failure) were recorded and analyzed for clinical results.

Surgical procedure

The operations in this series were performed under general anaesthesia by the same surgeon at a mean of 3.2 days (range, 1–12 days) after injury. Each patient was placed in the supine

position on a radiolucent operating table with the injured arm in a position of 90° abduction. The surgeon was on the cephalic side. The incision was approximately 6–8 cm long and made at the fracture site on the anterior-lateral forearm. The radial nerve was exposed between the brachialis and brachioradialis muscles and identified to ensure the safety of the operation. The brachialis was split parallel with its fibre between the middle third and lateral third, and the fracture site was defined. The fracture fragments were reduced under direct vision and fixed preliminarily with lag screws. A sub-muscular extraperiosteal tunnel was generated between the brachialis muscle and the periosteum using a periosteal elevator. A long 3.5-mm locking compression plate (ULS, Zimmer Inc., Warsaw, IN; 10–14 holes) was preflexed to fit the anterior face of the humerus, inserted via the incision and placed proximally across the fracture. According to the fracture type, the distal end of the plate was positioned on the long side of both columns, either the medial or the lateral, to ensure distal fixation of at least two bicortical screws. After the two or three distal screws were fixed directly, the location of the proximal screw was set by the target device of the ULS, and a 0.5-cm incision was created for screw fixation. The sleeve was placed appropriately with the blunt dissection of the trocar. Stretching the surrounding skin, three proximal screws were safely fixed through the small hole with the protection of the sleeve.

Fig. 1 **A** Exposing the radial nerve and reducing the fracture with a lag screw. **B** Diopter of the ULS. **C, D** Pre-operative X-rays. **E** A radiograph with a C-arm during the operation



Successful fracture reduction and proper positioning of the plate and screws were confirmed under fluoroscopic guidance. Elbow flexion without block was confirmed. The wound was closed, and a drainage tube was positioned through the proximal small hole. No external immobilization was used (Fig. 1).

To avoid haematoma formation, drainage was maintained for one to two days after the surgery. After removal of the drainage tube, the patient was instructed to begin ROM of the elbow and shoulder. Daily activities and light manual labour were gradually resumed. All patients were followed post-

operatively with clinical and radiographic examinations at four-week intervals.

Results

Our series (Table 1) included 12 males and 16 females with a mean age of 30.8 years (range, 18–71 years). All of the fractures were unilateral. The dominant arm was injured in 11 patients (39.3%). The causes of injury were falls in 13 patients (46.4%), car accidents in nine (32.1%), arm wrestling in three

Table 1 Patient data, AO/OTA classifications and complications

Patient number	Sex	Age (years)	Side of injury	Dominant arm injured	Cause	AO/OTA classification	Complications
1	F	32	L		Fall	B1	None
2	M	18	L		Arm wrestling	A1	None
3	M	32	L		Fall	B1	None
4	F	21	R	Yes	Fall	A3	Ipsilateral clavicle fracture, Pelvic fracture, Multiple organ injury
5	F	27	L		Car accident	B1	None
6	F	30	R	Yes	Car accident	B1	None
7	F	31	L		Car accident	B1	None
8	F	30	L		Car accident	A1	Radial nerve injury
9	M	43	L	Yes	Car accident	B2	Ipsilateral radius fracture
10	M	43	R	Yes	Car accident	B1	None
11	F	37	R	Yes	Fall	B1	None
12	M	25	L		Arm wrestling	A1	None
13	M	23	L		Car accident	B2	Ipsilateral ulna fracture
14	F	40	L		Fall	A1	None
15	M	18	R		Arm wrestling	A1	None
16	M	27	L	Yes	Industrial accident	A3	Radial nerve injury, Ipsilateral clavicle fracture, Scapula fracture, Radius and ulna fracture,
17	F	24	L		Fall	A1	Radial nerve injury
18	F	71	R	Yes	Fall	B2	Radial nerve injury
19	F	25	L		Fall	A1	None
20	M	18	L		Fall	B1	None
21	F	27	R	Yes	Car accident	B1	None
22	F	24	L		Fall	A1	None
23	M	39	R	Yes	Throwing	A1	None
24	F	21	L		Fall	A3	None
25	M	32	R	Yes	Fall	B1	None
26	M	21	R	Yes	Throwing	A1	None
27	F	49	R		Fall	C1	Radial nerve injury, Pubic symphysis separation, Lumbar vertebra fracture
28	F	36	L		Car accident	C1	None

M male, F female, L left, R right

(10.7%), throwing in two (7.1%), and industrial accidents in one (3.6%). Five patients (17.9%) presented with pre-operative radial nerve palsy and five with multiple fractures. According to AO classification, all fractures were grouped as follows: A1 (10 cases, 35.7%), A3 (3 cases, 10.7%), B1 (10 cases, 35.7%), B2 (3 cases, 10.7%), C1 (2 cases, 7.1%).

The patients were followed for a mean duration of 21.6 months (range, 12–36 months). The mean operation time was 118 (SD \pm 29.5) minutes. All of the fractures were united, with a mean healing time of 3.5 (SD \pm 1.17) months. One patient exhibited delayed union (3.6%), with a union time of nine months. No nonunion, iatrogenic neuropraxia, or implant failure occurred. The five patients with pre-operative radial nerve palsy recovered after a mean duration of 8.7 (SD \pm 3.9) weeks. Elbow function was evaluated post-operatively at three months, and the average ROM was 135.18° (SD \pm 10.76), ranging from 110° to 150°. The mean DASH Score was 6.6, ranging from 0 to 24.2. For the MEP Score, 27 patients had excellent values (96.4%), and one had a good value (3.6%); no patients had fair or poor values. The average MEP Score was 96.6, ranging from 85 to 100. The average scar length was 6.8 (SD \pm 0.98) cm, and the shortest and longest scars were 4.5 cm and 8 cm, respectively (Fig. 2).

Discussion

The main goal of treatment of extra-articular distal humerus fractures is to restore alignment and achieve stable fixation to allow for early elbow ROM, which is crucial for a good functional outcome [4]. However, it is difficult to perform nail osteosynthesis in distal-third fractures because of the short distal fragment and the narrow medullary canal. The current literature suggests that plate and screw fixation via a posterior or lateral approach is a reliable and preferred technique for the surgical treatment of extra-articular fractures of the humerus [4, 5, 8–13]. Although a retrospective study of plate osteosynthesis via the anterior approach was reported by Kim et al., this series contained only throwing fractures [14]. In general, the antero-lateral approach is safely applied in most proximal and middle humerus fractures, whereas it is difficult to obtain sufficient fixation at the distal fragment in distal humerus fractures. Our series contained various causes of injury, ages and AO fracture types. For all patients, the operation was performed via the antero-lateral approach, and their fractures healed with satisfactory functional and radiographic results. There were no implant-related

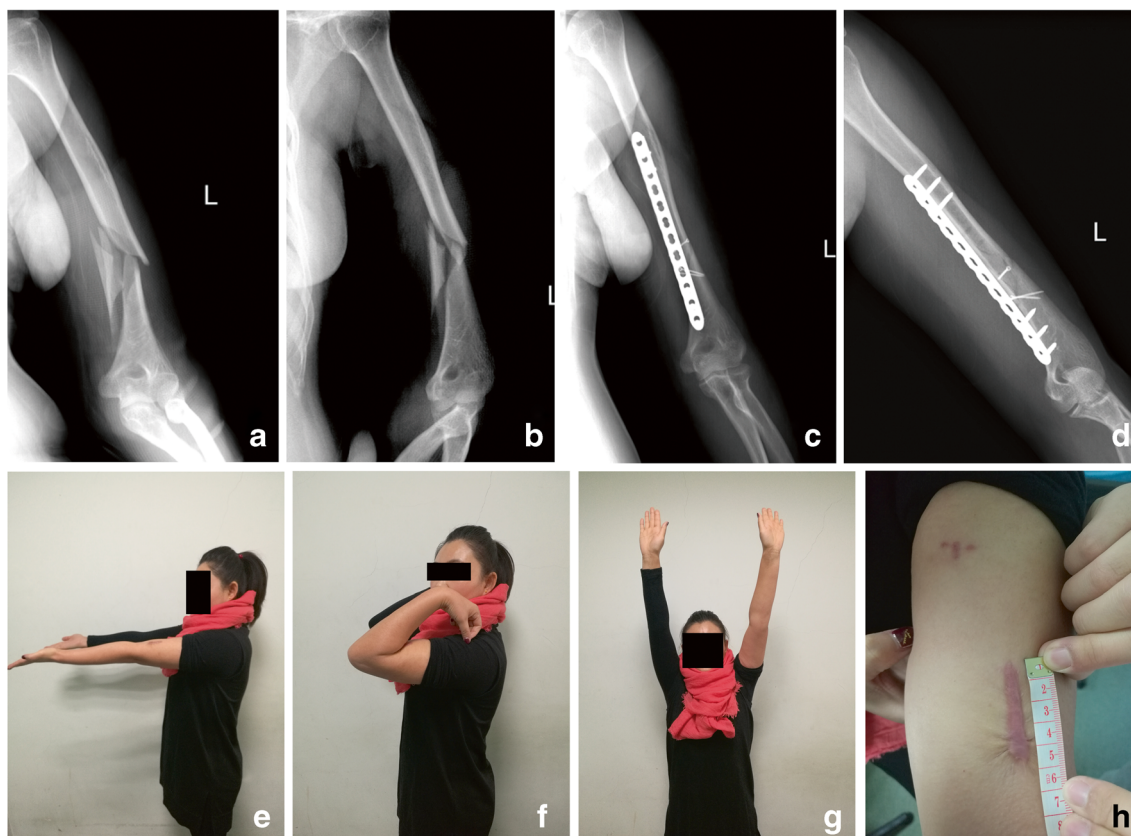


Fig. 2 A–H Patient number 28. A–D Pre- and post-operative X-rays. E, F, G The post-operative functional outcomes. H The length of the scar three months later

complications or iatrogenic radial nerve injury in this series. Our antero-lateral approach of the MIPO technique shows adequate fixation results, with minimal interference to the radial nerve.

Dual plating or a large of number of screws at the distal fragment (LCP metaphyseal plate and extra-articular distal humerus plate) has been suggested for security fixation in distal-third fractures of the humerus [4, 5, 12, 13, 15]. In a multi-centered retrospective study, Meloy et al. compared dual-columnar plating to single plating of extra-articular distal humerus fractures. These authors found that patients treated with single-column plating had similar union rates and alignment as dual-column plating, but with significantly better ROM and fewer complications [16]. Compared with other reports of posterior and lateral approaches, we inserted only two or three locking screws at the distal fragment via the anterior-lateral approach. It can be argued that the use of only two screws might compromise the stability of fixation, especially in elderly patients with poor bone quality and in highly comminuted fractures. Nonetheless, in our series, excellent results of fracture union and arm function without external immobilization postoperatively were achieved for one 71-year-old patient and two patients with C1 fractures. Based on a cadaver study of the osteoporotic humeral shaft, Hak et al. showed that two locking screws per segment are sufficient and that the addition of a third screw in the locked plate construct did not add to mechanical stability for axial loading, bending, or torsion [17]. Fixation of more screws is still an effective method of avoiding the complication of implant failure. Thus, to overcome the limitation of fewer screws, anatomic reduction with lag screws and a long locking compression plate were managed in all patients, as some studies have described that solid screws can increase construct stability dramatically [18] and that bending strength in long bone fractures can be augmented by increased plate length and bridge length [19, 20].

Iatrogenic radial nerve palsy is common in the treatment of distal-third fractures of the humerus. Claessen et al. analyzed 325 patients with diaphyseal humerus fracture who underwent operative treatment and found that the surgical approach was associated with iatrogenic radial nerve palsy. This complication occurred in 22% of patients treated via a lateral approach, 11% via a posterior approach, and 4% via an anterior-lateral approach [21]. When using the posterior and lateral approaches, the radial nerve must be identified and mobilized with a long segment, allowing the plate to be placed under the nerve. With an appropriate antero-lateral approach, the radial nerve can readily be exposed between the brachialis and brachioradialis muscles and be protected in the muscle fibre during the procedure. In addition, the plate can be placed in a relatively safe position away from the radial nerve with direct visualization. Implant irritation is another possible

complication of the operation using the posterior approach, resulting in pain and reoperation because of the thin soft tissue covering [4, 12].

The MIPO technique for distal-third humerus fractures has recently been reported [22–24]. The anterior MIPO technique for mid-distal humeral shaft fractures was described by An et al. and compared with conventional open reduction [22]. In their series, the radial nerve was not exposed during the operative procedures. Livani et al. performed ultrasonographic measurement of the distance between the radial nerve and the implant material with the anterior MIPO procedure and revealed that the nerve is quite close to the plate, especially in the distal third fractures (mean 4.0 mm) [25]. Therefore, percutaneous plate insertion is a dangerous procedure without the radial nerve exploration, for the high risk of nerve entrapment. Zogbi et al. described a MIPO technique with the lateral approach, though the iatrogenic radial nerve palsy rate was as high as 42.9% (3/7), even though the radial nerve was visualized during the surgery [23]. Gallucci reported posterior MIPO for distal-third humeral shaft fractures, with a 5% (1/21) rate of iatrogenic radial nerve palsy and a 76.2% (16/21) rate of varus deformity [24]. In general, MIPO is not considered suitable for fractures in the distal-third humerus due to the risk of radial nerve injury and deformity caused by indirect reduction [15]. In our procedure, the reduction of fractures and radial nerve exploration can be achieved in a minimal incision, and fixation of proximal screws can be safely managed by the target device through a small hole. In our series, the average scar length was 6.8 cm, and the shortest was 4.5 cm.

The limitations of this study include the relatively small sample size and the few elderly and comminuted fracture patients. In addition, we did not have a control group with which to compare the effectiveness of our technique.

Conclusion

For extra-articular distal humerus fractures, a MIPO operation via the anterior-lateral approach results in satisfactory clinical and radiographic outcomes. This approach may be considered a surgical option, offering advantages of sufficient fixation, fewer complications, less invasion and scarring, and excellent functional results.

Compliance with ethical standards

Ethical approval It is certified that the submission by the author Wei Zhao, Department of Orthopedics, First Affiliated Hospital Of Dalian Medical University (approval number: LCKY2016–44), is in accordance with institutional medical ethics requirements. After the review, the hospital medical ethics committee agreed with the report.

Authorship declaration All authors listed meet the authorship criteria according to the latest guidelines of the International Committee of Medical Journal Editors, and all authors are in agreement with the manuscript.

Disclosure statement The authors declare that they have no conflict of interest.

References

- Court-Brown CM, Caesar B (2006) Epidemiology of adult fractures: a review. *Injury* 37(8):691–697. doi:10.1016/j.injury.2006.04.130
- Sarmiento A, Horowitch A, Abouafia A, Vangness CT (1990) Functional bracing for comminuted extra-articular fractures of the distal third of the humerus. *J Bone Joint Surg Br* 72(2):283–287
- Jawa A, McCarty P, Doornberg J, Harris M, Ring D (2006) Extra-articular distal-third diaphyseal fractures of the humerus. *J Bone Joint Surg* 88(11):2343–2347. doi:10.2106/jbjs.f.00334
- Capo JT, Debkowska MP, Liporace F, Beutel BG, Melamed E (2014) Outcomes of distal humerus diaphyseal injuries fixed with a single-column anatomic plate. *Int Orthop* 38(5):1037–1043. doi:10.1007/s00264-013-2213-x
- Prasam ML, Ahn J, Paul O, Morris EM, Kalandiak SP, Helfet DL, Lorich DG (2011) Dual plating for fractures of the distal third of the humeral shaft. *J Orthop Trauma* 25(1):57–63. doi:10.1097/BOT.0b013e3181df96a7
- Livani B, Belangero W, de Medeiros RC (2006) Fractures of the distal third of the humerus with palsy of the radial nerve managed using minimally-invasive percutaneous plate osteosynthesis. *J Bone Joint Surg Br* 88(12):1625–1628. doi:10.1302/0301-620x.88b12.17924
- Zhiquan A, Bingfang Z, Yeming W, Chi Z, Peiyan H (2007) Minimally invasive plating osteosynthesis (MIPO) of middle and distal third humeral shaft fractures. *J Orthop Trauma* 21(9):628–633. doi:10.1097/BOT.0b013e31815928c2
- Levy JC, Kalandiak SP, Hutson JJ, Zych G (2005) An alternative method of osteosynthesis for distal humeral shaft fractures. *J Orthop Trauma* 19(1):43–47. doi:10.1097/00005131-200501000-00008
- Kumar MN, Ravishankar MR, Manur R (2015) Single locking compression plate fixation of extra-articular distal humeral fractures. *J Orthop Traumatol* 16(2):99–104. doi:10.1007/s10195-014-0325-8
- Illical EM, Farrell DJ, Siska PA, Evans AR, Gruen GS, Tarkin IS (2014) Comparison of outcomes after triceps split versus sparing surgery for extra-articular distal humerus fractures. *Injury* 45(10):1545–1548. doi:10.1016/j.injury.2014.04.015
- Yin P, Zhang L, Mao Z, Zhao Y, Zhang Q, Tao S, Liang X, Zhang H, Lv H, Li T, Tang P (2014) Comparison of lateral and posterior surgical approach in management of extra-articular distal humeral shaft fractures. *Injury* 45(7):1121–1125. doi:10.1016/j.injury.2014.02.034
- Scolaro JA, Voleti P, Makani A, Namdari S, Mirza A, Mehta S (2014) Surgical fixation of extra-articular distal humerus fractures with a posterolateral plate through a triceps-reflecting technique. *J Shoulder Elb Surg* 23(2):251–257. doi:10.1016/j.jse.2013.09.020
- Spitzer AB, Davidovitch RI, Egol KA (2009) Use of a “hybrid” locking plate for complex metaphyseal fractures and nonunions about the humerus. *Injury* 40(3):240–244. doi:10.1016/j.injury.2008.07.019
- Kim SJ, Lee SH, Son H, Lee BG (2015) Surgical result of plate osteosynthesis using a locking plate system through an anterior humeral approach for distal shaft fracture of the humerus that occurred during a throwing motion. *Int Orthop (SICOT)* 40(7):1489–1494. doi:10.1007/s00264-015-2895-3
- Lee J-K, Choi Y-S, Sim Y-S, Choi D-S, Han S-H (2016) Dual plate fixation on distal third diaphyseal fracture of the humerus. *Int Orthop (SICOT)*:1–7. doi:10.1007/s00264-016-3355-4
- Meloy GM, Mormino MA, Siska PA, Tarkin IS (2013) A paradigm shift in the surgical reconstruction of extra-articular distal humeral fractures: single-column plating. *Injury* 44(11):1620–1624. doi:10.1016/j.injury.2013.07.005
- Hak DJ, Althausen P, Hazelwood SJ (2010) Locked plate fixation of osteoporotic humeral shaft fractures: are two locking screws per segment enough? *J Orthop Trauma* 24(4):207–211. doi:10.1097/BOT.0b013e3181bdd1da
- McKee MD, Larsson S (2009) Humeral shaft fractures. In: Bucholz RW, Heckman JD, Court-Brown CM, Tometta P (eds) *Rockwood and Green’s fractures in adults*, vol 7. Lippincott Williams & Wilkins, Philadelphia, pp 1000–1017
- Sanders R, Haidukewych GJ, Milne T, Dennis J, Latta LL (2002) Minimal versus maximal plate fixation techniques of the ulna: the biomechanical effect of number of screws and plate length. *J Orthop Trauma* 16(3):166–171. doi:10.1097/00005131-200203000-00005
- Stoffel K, Stachowiak G, Forster T, Gächter A, Kuster M (2004) Oblique screws at the plate ends increase the fixation strength in synthetic bone test medium. *J Orthop Trauma* 18(9):611–616. doi:10.1097/00005131-200410000-00006
- Claessen FM, Peters RM, Verbeek DO, Helfet DL, Ring D (2015) Factors associated with radial nerve palsy after operative treatment of diaphyseal humeral shaft fractures. *J Shoulder Elb Surg* 24(11):e307–e311. doi:10.1016/j.jse.2015.07.012
- An ZQ, Zeng BF, He XJ, Chen Q, Hu SD (2010) Plating osteosynthesis of mid-distal humeral shaft fractures: minimally invasive versus conventional open reduction technique. *Int Orthop (SICOT)* 34:131–135. doi:10.1007/s00264-009-0753-x
- Gallucci G, Boretto J, Alfie V, Donndorff A, De Carli P (2015) Posterior minimally invasive plate osteosynthesis (MIPO) of distal third humeral shaft fractures with segmental isolation of the radial nerve. *Chirurgie de la main* 34(5):221–226. doi:10.1016/j.main.2015.06.007
- Zogbi DR, Terrivel AM, Mouraria GG, Mongon ML, Kikuta FK, Filho AZ (2014) Fracture of distal humerus: MIPO technique with visualization of the radial nerve. *Acta Orthop Bras* 22(6):300–303. doi:10.1590/1413-78522014220601003
- Livani B, Belangero W, Andrade K, Zuiani G, Pratali R (2009) Is MIPO in humeral shaft fractures really safe? Postoperative ultrasonographic evaluation. *Int Orthop (SICOT)* 33:1719–1723. doi:10.1007/s00264-008-0616-x