



Minimally invasive plate osteosynthesis in humerus nonunion after intramedullary nailing

Christian Allende¹ · Fernando Vanoli¹ · Luciano Gentile¹ · Natalia Gutierrez¹

Received: 22 September 2017 / Accepted: 16 March 2018 / Published online: 24 March 2018
© SICOT aisbl 2018

Abstract

Introduction The purpose of this study was to evaluate the results achieved after the use of lateral minimally invasive plate osteosynthesis (MIPO) in oligotrophic humerus nonunions resulting from failed intramedullary nailing (IM).

Method We evaluated nine patients with humerus nonunion after failed locked intramedullary nailing, all treated using 3.5-mm locked compression plates (LCP) placed through lateral minimally invasive approaches, between 2010 and 2016. Patient's age averaged 39.7 years. All nonunions were diaphyseal and oligotrophic. All nonunions had previous surgical treatment with static locked nails (seven antegrade and two retrograde). The IM nails were all well inserted in the humerus (none of them protruded or had rotator cuff lesions associated). Pre-operative Disabilities of the Arm, Shoulder and Hand (DASH) score averaged 25.5 points. Pre-operative Constant's score averaged 80.2. Pre-operative visual analog scale of pain averaged 2.4 points.

Results Follow-up averaged 17.7 months. Time between initial surgery and revision procedure averaged 11.7 months. Union was achieved in all cases, after an average of 4.8 months. DASH score at last follow-up averaged 5.1 points, and final Constant's score averaged 93.7 points. The analog scale of pain averaged 0.7 points. Time from definitive surgery to work return averaged 3.9 months. Long 3.5-mm LCPs were used (plate length averaged 16.9 screw holes). In two cases, a third 4-cm incision at the nonunion site was performed and cancellous autologous iliac crest bone graft was associated.

Conclusion In our series of nine patients, we achieved union and good objective and subjective results, with high patient satisfaction, using a lateral MIPO technique and placing long 3.5-mm LCPs in selected oligotrophic humerus nonunions after failed IM nailing.

Keywords Humerus diaphyseal nonunion · Failed intramedullary nailing · Minimally invasive plating

Clinical results achieved with the use of locked intramedullary nails (IM) in the humerus have not been as consistent as those obtained with similar systems used in lower extremities [1]. Locked nailing in humeral fractures allows achieving similar union rates than those obtained when using the gold standard open reduction and internal fixation (ORIF) with plates [2–4]. There is literature reporting that IM nails are associated to a higher risk of restriction in shoulder range of motion and a more frequent need of implant removal than when compression plates are used. There are also reports stating that results after surgical treatment of diaphyseal humerus nonunions are worse in patients treated previously with IM nailing, than in those patients

with no previous surgical treatment or those treated initially with plates; and it has been shown that exchanging nails, when a humerus fracture treated with a nail fails to unite, has not been associated to good results [1]. There are reports on open reduction and internal fixation using different types of plates, leaving the IM nail in situ [4–8]; but there are only two previous reports on minimally invasive plate osteosynthesis (MIPO) for treatment of humeral shaft nonunions, and they both include a wide variety of nonunion types and aetiologies [9, 10].

The purpose of this study was to evaluate the results achieved after the use of MIPO in oligotrophic humerus nonunions with failed IM nailing.

✉ Christian Allende
christian_allende@hotmail.com

¹ Instituto Allende de Cirugía Reconstructiva, Sanatorio Allende, Hipólito Yrigoyen 384, 5000 Córdoba, Argentina

Material and methods

We evaluated nine patients with humerus nonunion after failed IM nailing, treated by MIPO between 2010 and 2016.

Patient's age averaged 39.7 years (range, 21 to 57). All cases evidenced radiographic lack of callus formation and a gap at the fracture site. All nonunions were diaphyseal and oligotrophic [11]. The dominant upper extremity was affected in four cases. All nonunions had previous surgical treatment with static locked nails (seven antegrade and two retrograde); eight nails were locked proximally and distally, and one only proximally. The IM nails were all well inserted in the humerus (none of them protruded or had rotator cuff lesions associated), and its removal was considered technically demanding (Fig. 1a). Four patients had had polytrauma initially, one patient was diabetic and obese, and one patient had had radial nerve palsy during nail placement (completely recovered at the time of revision surgery).

Pre-operative Disabilities of the Arm, Shoulder and Hand (DASH) score averaged 25.5 points (range, 8 to 67). Pre-operative Constant's score averaged 80.2 (range, 54 to 95). Pre-operative visual analog scale of pain averaged 2.4 points (range, 0 to 4). All but one patient had complete elbow range of motion (the patient with limited motion had lack of 25° of extension).

Patients were placed in bend chair position under supraclavicular nerve block anesthesia. A lateral approach with two incisions was used: one proximal lateral transdeltoid approach, starting at the tip of the acromion, and another distal approach in which the radial nerve was released and protected, the length of the approaches ranged from 4 to 6 cm (Fig. 1b); after the approaches were performed and the nerve released, the plates were bended in their proximal 1/3 to fit the anatomy of the proximal humerus (Fig. 1c), and then slid from proximal to distal. IM nails were dinamized by removing the distal locking screw in four cases, one nail was not locked distally, and the remaining four nails were not dinamized. Long 3.5-mm locked compression plates (LCP) were used (plate length averaged 16.9 screw holes) (range, 12 to 20). In two cases in which, after performing MIPO, a clear gap at the nonunion site was evidenced, a third lateral 4-cm approach at the nonunion site was performed, followed by decortication of the anterior aspect of the nonunion (with an osteotome under fluoroscopic guidance) and cancellous autologous iliac crest bone graft (obtained using a 12-mm trephine and curettes) was placed between the nonunion and the decorticated anterior aspect of the humerus. In the remaining seven cases, the nonunion site was not opened or decorticated and no bone graft or substitutes were associated.

Results

Follow-up averaged 17.7 months (range, 12 to 36). Time between initial surgery, in which the IM nail was placed, and revision surgery averaged 11.7 months (range, 7 to 17). Union was achieved in all cases, after an average of 4.8 months

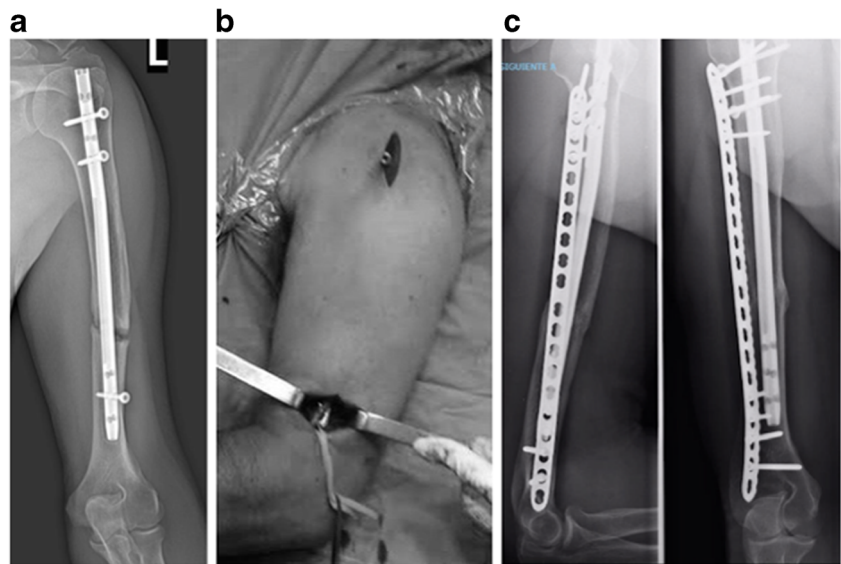
(range, 3 to 7). DASH score at last follow-up averaged 5.1 points (range, 0 to 17), and final Constant's score averaged 93.7 points (range, 88 to 100). All patients had complete elbow function at last follow-up. The analog scale of pain averaged 0.7 points (range, 0 to 2). Time from definitive surgery to work return averaged 3.9 months (range, 1 to 9). All patients returned home the same day of the procedure. There were no infections or post-operative nerve compromise. None of the patients needed implant removal; although, one patient refers some occasional discomfort at the distal tip of the plate when performing forced activities.

Discussion

Diaphyseal humerus nonunions after IM nailing have become a less frequent complication since the introduction of locking nails. Plates are the treatment of choice for humerus nonunions according to the literature [1, 9]. External fixators can be associated to re-fractures, pin tract infections, septic arthritis, and nerve lesions; they represent voluminous constructions, and the extremity needs to be protected after their removal to decrease the chances of re-fracture [12, 13]. Nails have not been associated to good results in humerus nonunions [9, 14, 15]. In our series of patients, we achieved bony union and good functional results, avoiding extensive exposures, using a lateral MIPO technique and placing long 3.5-mm LCPs, in selected oligotrophic humerus nonunions that occurred after locked IM nailing. We used the technique in diaphyseal oligotrophic nonunions in which we considered that only mechanical stability was necessary, when the previously placed nails did not protrude proximally, there was no evidence of rotator cuff lesion, and their removal was considered technically demanding.

Good results have been reported with the use of MIPO in humerus fractures, but there are only two retrospective reports on their use in humerus nonunions [9, 10]. Ji et al. in 2009 [16] presented a paper on MIPO technique applied in the treatment of humeral shaft fractures through the lateral approach, evidencing that it is safe, and concluded that there is no risk of axillary nerve injury when using this approach; but, Rancan et al. in 2010 [17] emphasize the importance of performing adequate surgical technique, including anatomical soft tissue dissection and correct hardware insertion, to avoid damage to the axillary or radial nerve; in our series, there were no axillary or radial nerve compromise using a lateral MIPO technique. One report was by Vilaca and Uezumi [10] in 2012, they reported on 15 cases in which they performed anterior MIPO using 4.5-mm dynamic compression plates (DCP) in 11 cases or LCPs in 4 cases, for humeral shaft nonunions with good results concerning union and function, but their series was not homogeneous and included patients with nonunions without previous surgical treatment (7 cases) and patients with

Fig. 1 **a** Male patient with an oligotrophic diaphyseal humerus nonunion. Fifteen months after locked intramedullary nailing, evidencing radiographic lack of callus formation, and loosening of the IM nail. **b** MIPO through a lateral approach with two incisions, protecting and releasing the radial nerve distally, using a long 3.5-mm LCP bridging the nonunion. **c** Final follow-up showing radiographic bony union



nonunions that had had previous surgical treatment for their humerus fracture (plates in 5 cases and nails in three cases (but they do not specify what type of IM nailing)); they used a 3-cm auxiliary incision over the nonunion site to add cancellous bone graft in the 12 atrophic nonunions; the authors remarked the advantage of no radial nerve dissection needed when using anterior humeral plating. The second report was by Allende et al. [9] in 2014, and the authors included 32 patients with humerus nonunion revised with plates after failed nailing; in seven of those cases, the nails were left in situ, and only in three of those cases MIPO was used, achieving union and good functional results. Our report includes a homogenous group of patients in which lateral MIPO technique for humerus nonunions after failed IM nailing was performed using a long 3.5-mm LCP bridging the nonunion, allowing good functional and aesthetic results, with very low morbidity and pain, prompt return to work and a one day hospitalization. The main limitations of our study are the number of patients included and not having a control group.

Wu in 1996 proposed associating a staple in nonunions treated with intramedullary nails [18]; Emmerson and Sher in 1998 [5], Gerber et al. in 2003 [6], Ring and Jupiter in 2004 [7], and Nadkarni et al. in 2008 [8] reported on ORIF using different types of plates, leaving the IM nail in situ; in all their cases, the combined osteosynthesis was performed to increase rotational stability at the nonunion, reporting excellent results and union in all cases. When the IM nail protrudes at its entry point, it should be removed; but, when the nails are placed deep in the medullary canal, they can be difficult to find and remove, and during their removal there is risk of additional rotator cuff lesion [9]. In these cases, leaving the nail and associating a plate is a valid treatment alternative. When the decision is to leave the nail in place and to associate a plate to increase stability, it is important to evaluate (a) type of IM nail used (to determine if it has a locking system, and if

it protrudes proximally or distally), (b) type of nonunion (to determine if there is bone contact and the extension of the bone defect), and (c) amount of the medullary canal occupied by the IM nail (to determine the length of the plate and type and direction of the screws to be used) [9]. Leaving the nail in situ eliminates the risk of shoulder damage; it reduces operative time compared to revision by removal of previous implants and helps reducing patient's hospitalization time (all patients in our series were performed in day hospital).

Humeral nonunions after prior intramedullary nailing can be difficult to address due to possible bone loss around a loose nail or locking bolts, which complicates the reconstructive procedure and leads to poorer operative results compared to prior non-operative treatment or plate fixation [14]; if untreated, osteolysis and bone loss around the nail and locking screws complicate the reconstructive surgical procedure, and increase the risk of secondary fractures [4, 19]. Another major concern may be the risk of stress riser fractures when combining IM nails and plates [4]; to minimize the stress rising effect, placing the distal end of the plate surpassing the nail tip is recommended, as it will allow placement of screws distal to the nail tip and the area eroded by the windshield effect and the loose distal bolts.

The use of long bridge plates allowed increasing the pull-out resistance of the implants, by increasing their working length and flexibility (plate length in our series averaged 16.9 screw holes) [6]. The use of LCPs has the advantage of allowing improved fixation in thin humerus cortices resulting from the windshield effect after loose IM nails, as well as in those cases in which the nail is left in situ, by the use of monocortical screws in the areas where the nail occupies most of the medullary canal and do not allow placement of bicortical screws. The use of plates placed without removing the IM nail helps in improving the interface between bone and IM nail, as the screws act by compressing the loose nail against the humeral cortex, improving bone-nail interface,

and increasing stability of the construction [9]. Lateral placement of the plate has the advantage of allowing more distal placement of the implant than when placed through an anterior MIPO technique as described by Vilaca and Uezumi [10] (when placed anteriorly, the plate tip should not enter the coronoid fossa to avoid decreasing elbow ROM; while when placed laterally, its more distal placement allows placing more screws distal to the tip of the nail left in situ, overpassing the distal nail tip, where most of its windshield effect is normally evidenced).

Gessmann et al. [4] reported a series in which they used an anterior plate (4.5 mm low contact DCP in 32 cases, 3.5-mm low contact DCP in 4 cases, and an LCP in one case), associated with Iliac crest bone graft in humeral shaft nonunions after intramedullary nailing. They achieved 97% consolidation rate; nine out of 37 patients in their series needed removal of both the intramedullary nail and the augmentation plate because they complained of a foreign body sensation around the anterior plate, and one patient suffered a periimplant stress fracture at the distal end of the nail and plate (although successfully treated by changing the plate to a longer one, the authors emphasize the importance of not placing the ending of the augmentation plate near the IM nail tip). In our series, although smaller, there was also high union rate (all cases), but none of the patients needed implant removal (probably because we used 3.5-mm plates instead of 4.5-mm plates and that the plates were placed laterally instead of anteriorly as reported by Gessman et al. [4]); and we used longer plates overpassing the nails distal tip, which decreases the chances of periimplant fractures.

Nonunion is a serious complication after internal fixation of humeral shaft fractures. Success in achieving union and good functional results in humerus nonunions is based in many biological and mechanical factors; and although implant selection and surgical technique are important factors to be considered, they are only two of the many aspects that must be evaluated and considered before approaching this pathology. Avoiding unnecessary surgical procedures and performing adequate surgical techniques, in the initial treatment of humerus fractures, are basic concepts that allow decreasing the incidence of nonunion after IM humerus nailing. Most failures are due to inadequate surgical indication, implant selection, or surgical technique [9, 11, 20, 21]. Nonunion biological and treatment concepts have evolved since the reports made by Reed et al. in 2002, demonstrating that even atrophic nonunions are not avascular [22]; and Ramoutar et al. in 2011, which conclude that stable fixation is essential in nonunion treatment, but the routine use of autologous bone graft may not be necessary in nonunion [23]. In our series, stable fixation was achieved in all cases by combining the IM nail with a long 3.5-mm LCP, and bone graft was added at the nonunion site in only two cases in which an evident gap persisted at the nonunion after plate placement.

In our series of nine patients, we had good objective and subjective results, with high patient satisfaction, using a lateral MIPO technique and placing long 3.5-mm LCPs in selected oligotrophic humerus nonunions after failed IM nailing.

Funding There is no funding source.

Compliance with ethical standards

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

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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

References

1. Brinker MR, O'Connor DP (2007) Exchange nailing of ununited fractures. *J Bone Joint Surg Am* 89:177–188
2. Ouyang H, Xiong J, Xiang P et al (2013) Plate versus intramedullary nail fixation in the treatment of humeral shaft fractures: an updated meta-analysis. *J Shoulder Elb Surg* 22:387–395
3. Kurup H, Hossain M, Andrew JG (2011) Dynamic compression plating versus locked intramedullary nailing for humeral shaft fractures in adults. *Cochrane Database Syst Rev* *Cochrane Database Syst Rev*. (6): CD005959
4. Gessmann J, Konigshausen M, Coulibaly MO et al (2016) Anterior augmentation plating of aseptic humeral shaft nonunions after intramedullary nailing. *Arch Orthop Trauma Surg* 136:631–638
5. Emmerson KP, Sher JL (1998) A method of treatment of nonunion of humeral shaft fractures following treatment by locked intramedullary nail: a report of three cases. *Injury* 29:550–552
6. Gerber A, Marti R, Jupiter J (2003) Surgical management of diaphyseal humerus nonunion after intramedullary nailing: wave-plate fixation and autologous bone grafting without nail removal. *J Shoulder Elb Surg* 12:309–313
7. Ring D, Jupiter J (2004) Humerus nonunion after intramedullary rod fixation. Locking compression plate without removing the nail. *Tech Orthop* 18:356–359
8. Nadkarni B, Srivastav SH, Mittal V, Agarwal SH (2008) Use of locking compression plates for long bone nonunions without removing existing intramedullary nail: review of literature and our experience. *J Trauma* 65:482–486
9. Allende C, Paz A, Altube G et al (2014) Revision with plates of humerus nonunions secondary to failed intramedullary nailing. *Int Orthop* 38:899–903
10. Vilaca PR, Uezumi MK (2012) Anterior minimally invasive bridge-plate technique for treatment of humeral shaft nonunion. *J Orthopaed Traumatol* 13:211–216
11. Weber BG, Pseudoarthrosis CO (1976) Pathophysiology, biomechanics, therapy, results. Huber, Bern
12. Lammens J, Bauduin G, Driesen R et al (1998) Treatment of nonunion of the humerus using the Ilizarov external fixator. *Clin Orthop Relat Res* 353:223–230
13. Patel VR, Menon DK, Pool RD, Simonis RB (2000) Nonunion of the humerus after failure of surgical treatment. Management using the Ilizarov circular fixator. *J Bone Joint Surg Br* 82:977–983

14. McKee MD, Miranda MA, Riemer BL (1996) Management of humeral nonunion after the failure of locking intramedullary nails. *J Orthop Trauma* 10:492–499
15. Dujardin FH, Mazirt N, Tobenas AC et al (2000) Failure of locked centro-medullary nailing in pseudarthrosis of the humeral diaphysis. *Rev Chir Orthop Reparatrice Appar Mot* 86:773–780
16. Ji F, Tong D, Tang H et al (2009) Minimally invasive percutaneous plate osteosynthesis (MIPPO) technique applied in the treatment of humeral shaft distal fractures through a lateral approach. *Int Orthop* 33:543–547
17. Rancan M, Dietrich M, Lamdark T et al (2010) Minimal invasive long Philos plate osteosynthesis in methaphyseal fractures of the proximal humerus. *Injury* 41:1277–1283
18. Wu CC (1996) Humeral shaft nonunion treated by a Seidel interlocking nail with a supplementary staple. *Clin Orthop* 326: 203–208
19. Flinkkila T, Ristiniemi J, Hamalainen M (2001) Nonunion after intramedullary nailing of humeral shaft fractures. *J Trauma* 50: 540–544
20. Anglen JO, Archdeacon MT, Cannada LK et al (2009) Avoiding complications in the treatment of humeral fractures. *Instr Course Lect* 58:3–11
21. Rommens PM, Kuechle R, Bord T et al (2008) Humeral nailing revisited. *Injury* 39:1319–1328
22. Reed AA, Joyner CJ, Brownlow HC, Simpson AH (2002) Human atrophic fracture non-unions are not avascular. *J Orthop Res* 20: 593–599
23. Ramoutar DN, Rodrigues J, Quah C et al (2011) Decortication and compression plate fixation of long bone non-union: is bone graft necessary? *Injury* 42:24–1434