How to treat proximal and middle one-third humeral shaft fractures: the role of helical plates

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Abstract

Purpose To evaluate the outcomes of patients affected by proximal and middle one-third humeral shaft fractures treated with helical plates.

Material and methods From October 2016 to June 2020, twenty-four (twenty women, four men) underwent humeral reduction and fixation with helical plates (A.L.P.S.® Proximal Humeral Plating System, Zimmer Biomet) that preserve deltoid muscle insertion and reduce the risk of iatrogenic radial nerve injury. At one and six months after surgery, standard antero-posterior and lateral radiographs were obtained, and at last follow-up (eighteen months on average), clinical evaluation was performed through range of motion assessment, Constant score and DASH score questionnaires. Only descriptive statistical analysis was conducted.

Results At six months, all fractures have healed. At last follow-up (average eighteen months, 13–28) mean Constant score was 71 (range 33–96), mean Dash score was 19.2 (range 1.7–63). The average range of motion was calculated as follows: flexion 137.8° (range 90–180); abduction 125.8° (range 85–180°); external rotation 55° (range 20–80°), internal rotation at L3 (range between scapulae-trochanter). Three patients experienced temporary radial nerve palsy from injury, while in one case, a temporary iatrogenic palsy occurred.

Conclusions In our opinion, the helical plate may be an effective surgical tool for management of proximal and middle one-third diaphyseal humeral fractures. The humeral helical plate allows stable fixation avoiding the deltoid tuberosity proximally and radial nerve distally, thus increasing the possibility of rapid functional recovery after surgery.

Keywords Diaphyseal humeral fractures · Complex humeral fractures · Helical plates · Deltoid tuberosity

Introduction

Humeral shaft fractures account for approximately 3% of all orthopaedic injuries. [1]. Most humeral shaft fractures can be treated nonoperatively: studies in literature reported excellent results with high rates of bone union and functionally and aesthetically acceptable residual deformities [1–3] For displaced, open or pathological fractures, fractures of the proximal or distal third of the shaft and fractures with ipsilateral brachial plexus or vascular injuries operative treatment have gained popularity and several options exist based on bone quality, type of fracture, its location, associated soft tissue injuries [1, 4].

Proximal and middle one-third diaphyseal humeral fractures, instead, are barely described in the literature and controversies exist about the ideal treatment. Studies analyzing intramedullary nail technique showed a higher risk of fixation failure in comminuted and osteoporotic bones and in fractures extending into the tuberosity or metaphysis [5, 6]; moreover, clinical series often reported debilitating shoulder complication due to nail insertion through the rotator cuff [1, 4]. Alternatively, locking plate fixation in humeral fractures has spread given the lesser degree of interference with elbow and shoulder function, rapid functional recovery and its stable fixation [5]. However, in proximal and middle third diaphyseal fractures...
plates have some limitations [5]; the radial nerve is at risk during the surgical approach at the middle diaphysis and detachment of the deltoid from its tuberosity is a common maneuver to accommodate the plate adequately, but this increases surgical trauma and may partially compromise the anterior part of the muscle [7]. The iatrogenic radial nerve injury is described in about 7% of cases (2.7–20%) [8], secondary to intraoperative traction rather than direct plating compression; this susceptibility is due to its fixed position in the sulcus radialis and its direct contact with the periosteum of the humerus after passing the medial intermuscular septum.

Regarding the deltoid detachment, in the past, some authors proposed manually twisting straight plates to avoid the deltoid insertion: despite satisfied results, it is unknown to what extent the twisting may weaken the plate, and the twisted head may accommodate fewer screws for the humeral head [9–12]. Other reports describe the application of helical plates on the humerus originally designed for other anatomical areas [5].

The literature that deals with helical plates is however scarce. With our study, we aim to describe our experience using helical plates specifically designed for the humerus (A.L.P.S.® Proximal Humeral Plating System, Zimmer Biomet) for the management of proximal and middle one-third diaphyseal fractures, reporting clinical evaluation of patients based on the range of motion measurement, the DASH Questionnaire and Constant score.

**Material and methods**

From October 2018 to June 2020, a double-center study was conducted at AZ Groeninge Hospital (Kortrijk, Belgium) and E. Agnelli Hospital (Pinerolo, Italy). We enrolled a consecutive series of adult patients that had complex humeral fractures involving the diaphysis and proximal metaphysis. Exclusion criteria were open or pathological fractures, patients with multiple injuries, fractures involving only the proximal or distal humerus, non-displaced fractures, patients unfit for surgery or non-compliant with the operative and post-operative protocol, patients followed for less than a year. Twenty-four patients (twenty women and four men) met inclusion criteria but one, a male patient, was excluded due to SARSCOV2 infection after a revision plate fixation for a failed nail treatment. Other three patients were excluded because of a short follow-up.

Finally, twenty people were included for clinical and radiographic evaluation. Injuries were mainly caused by high energy traumas or falls (Fig. 1). The mean age was 68 (43–84) years (Table 1). Using the AO classification, there were eight fractures for A group (A1 was the most frequent pattern), five fractures for B group, six fractures for C one; one periprosthetic fracture type A according to Wright and Cofield classification.

In three subjects (a spiral pattern in one case and a segmental one in the other two patients), a complete posttraumatic radial nerve palsy was present.

Informed consent was obtained from all patients. All cases were treated consecutively by the same surgeons (G.P from AZ Groeninge Hospital and N.L from E. Agnelli Hospital) in a beach chair position and a deltopectoral approach. Distal fixation was performed via an extension of the incision distally along the anterolateral aspect of the diaphysis or via a second window. We used an armholder to allow stable positioning of the arm. After the incision of the deltopectoral fascia, the surgeon identified and protected the cephalic vein, dissected soft tissue medializing the biceps muscle and deepened to the bone, using Hohmann retractors and periosteal elevators for exposition. Careful attention was made to preserve the deltoid insertion; we preferred placing retractors at this level and not proximally to avoid circumflex nerve damages. In two fractures extended proximally, a slight release of the pectoral major was necessary to attach reduction clamps firmly to bone. The deltoid lever arm may be a contributing factor in fragment displacement and for this reason, we had to proceed with a partial release in 10% of our patients to obtain anatomical reduction, but the aim is to avoid deltoid detachment. A partial arm abduction can help the surgeon obtain a correct reduction without
violating the muscle; moreover, with a bridging technique, the minimal deltoid detachment is usually not necessary (Fig. 2). In cases with fractures extended distally the brachialis insertion, its split is necessary for correct fracture reduction and plate positioning. We needed to perform the muscle split in almost all our cases as we mainly used long plates, and to insert the distal screws (Fig. 3). After temporary reduction with clamps and satisfactory fluoroscopic view, definite fixation was performed: in fractures fragments suitable for anatomic fixation, cortical lag screws 3.5 mm were employed to stabilize fragments; finally, a helical plate with angular stability (A.L.P.S. ® Proximal Humeral Plating System, Zimmer Biomet) was positioned (Fig. 4). This newly designed implant helps surgeons avoid deltoid detachment: the plate has a twist at 90–120 mm on average from greater tuberosity, resulting in a lateral position proximally, posterior to the biceps tendon, and an anterior position distally. Because of individual anatomical differences and to avoid manual correction of the twist, although possible, the surgeon paid attention to obtain the correct angulation at the deltoid insertion level at first and fix the proximal and distal segments with screws subsequently. We used angular stability fixation to minimize periosteal devascularization: the Zimmer system offers different screw options depending on bone quality: cortical and cancellous locking screws, low profile non-locking screws, multi-directional locking screws. Non-locking and multi-directional screws may be an effective aid to obtain a better plate-bone congruence and fixation even in cases of suboptimal plating placement.

The distal anterior placement reduces the risk of direct radial nerve conflict. The proximal humeral plate is available in two height options (A low plate that sits two cm distal from the footplate of greater tuberosity and a high plate that sits one cm from the greater tuberosity and offers two additional screw holes proximally) based on direct screw fixation of the greater tuberosity or not. The maximal length is 14 holes (227–234 mm). In most of our patients (22 out of 24), we used 11 or 14 hole-plates (Fig. 2): the length and number of screws depended on fracture morphology, but we ensured three bicortical locking screws on each side at least and with the largest distance possible between them, following the AO technical indications for these fractures [13]. In the periprosthetic fracture, unicortical screws and/or cerclage were used.

| Cases | Sex/age | Mode of injury | AO classification | Follow up months | ROM (Flex/abd/ER/IR) | Constant score | Dash score |
|-------|---------|----------------|-------------------|-----------------|----------------------|--------------|------------|
| 1     | F/72    | Fall           | AO12C2            | 22              | 100/90/45/Lumbo-sacral junction | 80           | 15.8       |
| 2     | F/48    | Pedestrian     | AO 12C2           | 18              | 180/160/60/L3       | 94           | 9.5        |
| 3     | F/68    | Fall           | AO 12A1           | 19              | 180/120/60/L3       | 84           | 15.8       |
| 4     | F/84    | Fall           | AO 12C3           | 13              | 160/170/60/L3       | 96           | 9.5        |
| 5     | F/80    | Fall           | AO 12A1           | 13              | 90/90/20/Lumbo-sacral junction | 73           | 20         |
| 6     | F/60    | Fall           | AO 12B2           | 14              | 110/110/50/gluteus  | 58           | 42.5       |
| 7     | F/46    | Fall           | AO12B1            | 18              | 170/170/60/Th12     | 52           | 26.7       |
| 8     | F/81    | Fall           | AO 12B3           | 14              | 130/130/80/between scapulae | 73           | 5.6        |
| 9     | M/47    | Motor vehicle accident | AO 12C1       | 14              | 180/160/45/L3       | 84           | 18.5       |
| 10    | F/78    | Fall           | AO 12A1           | 28              | 160/160/80/between scapulae | 85           | 2.5        |
| 11    | F/73    | Fall           | AO 12B3           | 27              | 140/110/45/between scapulae | 71           | 3.6        |
| 12    | F/74    | Fall           | AO 12A1           | 21              | 95/90/30/L3         | 57           | 33         |
| 13    | F/43    | Fall           | AO 12A1           | 18              | 115/115/60/Th12     | 67           | 11.2       |
| 14    | F/77    | Fall           | AO12C3            | 14              | 100/110/30/trochanter | 33           | 63         |
| 15    | F/63    | Fall           | AO 12A1           | 16              | 155/130/80/between scapulae | 79           | 33.3       |
| 16    | F/76    | Fall           | AO 12A2           | 13              | 155/155/80/Th12     | 83           | 3.7        |
| 17    | F/71    | Fall           | AO 12C3           | 16              | 125/85/60/L3        | 56           | 23.2       |
| 18    | M/66    | Fall with bicycle | AO 12A1         | 15              | 180/180/80/between scapulae | 95           | 1.7        |
| 19    | M/70    | Fall           | AO 12B3           | 21              | 115/90/20/Lumbo-sacral junction | 48           | 20.4       |
| 20    | F/80    | Fall           | Periprosthetic fracture: Type A Wright and Cofield classification | 16          | 115/90/45/Th12     | 55           | 24.1       |
none of our cases, a bone graft was needed, but it could be a feasible option to add mechanical support in fractures with significant bone loss.

We explored the radial nerve in cases with post-traumatic nerve palsy and it was found continuous at the fracture site. After surgery, patients started gentle passive range of motion exercises of the shoulder and elbow the day after the operation; active motion as tolerated was allowed immediately to recover daily activities and progressively improved through physical therapy; weightbearing was postponed for 5–6 weeks.

Patients included were followed in the clinic for at least one year: at one and six months, standard antero-posterior and lateral radiographs were obtained (Figs. 5–6). Fractures were reported as united if the patient reported no or mild pain with radiographically bridging callus in 3 of 4 cortices in AP/lateral views, no widening fracture gaps, no loss of fracture reduction, nor implant failure. At a mean time
of eighteen months (13–28 months of follow-up), we performed a clinical evaluation with a range of movement measurements, and participants were asked to answer to Constant score and DASH Questionnaire (Table 1).

Results

We clinically evaluated twenty patients with an average follow-up period of eighteen months (range 13–28). There was one case of iatrogenic radial nerve palsy, probably due to the extensive approach needed to reduce the distal extension of the humeral fracture. At last follow-up available (fourteen months), radial nerve function continued to recover with persistent finger stiffness and pain; palsy was resolved (Fig. 7). No other cases of intraoperative complications were observed. Regarding the three patients with preoperative radial nerve palsy, a near-to-complete recovery was reached in the first case after eight months and in the second case after six months. In the last patient, instead, a nervous deficit was still present at the last follow-up (eight months from injury), although with progressive improvement at EMG analysis. The last two patients however were excluded from final clinical and functional evaluations because their follow up was less than a year.

All fractures healed uneventfully, as it was observed on radiographs at one and six months of follow-up (Figs. 5–6).

We only made descriptive statistical analysis due to the small numbers of our case series. The average range of motion at the last follow-up (one year at least) was flexion 137.8° (90–180°); abduction 125.8° (85–180°); external
rotation 55° (20–80°), internal rotation at L3 (between scapulae-trochanter). Average Constant Shoulder Score was 71 (33–96), average Dash score was 19.2 (range 1.7–63).

**Discussion**

Numerous articles in literature classify humeral fractures and differentiate among proximal, diaphyseal and distal segments [13–15]; however, proximal and middle one-third diaphyseal humeral fractures and the related treatment are little described.

Maresca and colleagues [6] proposed a new classification and guide for treatment of multifocal humeral fractures and distinguish three main groups: type A (fractures of the proximal and humeral shaft), type B (diaphysis alone), and type C (diaphysis and distal humerus). Within A group, three subgroups are proposed: type A1 (non-displaced fractures of the proximal humerus and displaced shaft fractures), type A2 (displaced fractures of the proximal humerus and shaft); type A3 (multifragmentary fractures of the proximal humerus extending to the diaphysis). In their study, the authors analysed three possible surgical treatment (external fixation, plate fixation, intramedullary nailing) and concluded that even if intramedullary nailing might be a good option for bifocal diaphyseal fractures, it cannot be recommended in displaced fractures of the proximal humerus and shaft due to difficult simultaneous reduction. Alternatively, plates with angular stability can be used in all three subgroups with successful results [6] these seem to be a feasible option to gain stable fixation and early mobilization also in osteoporotic bone.

An advantage of plate fixation in proximal humeral fractures is the congruence: the flat surface of the great tuberosity allows for screw fixation of the neck and head of the humerus [5]. Moving more distally, however, the presence of the deltoid insertion limits the placement of the plate on the lateral aspect of the bone. Due to this discordance in conventional plating, a partial or nearly complete detachment of the deltoid insertion is usually necessary [5]. Benninger and Meier [16] performed minimally invasive plate placement on eight cadavers and reported some important observations: the deltoid muscle has seven intramuscular tendons that create a V shaped insertion, where the middle part is the weakest; a lateral plate position may pose radial nerve at risk distally; the deltopectoral approach is safer than a deltoid split for the axillary nerve. The risk of nerve damage was studied by Robinson

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**Fig. 7** Patient 9; male, 47 years old, motor vehicle accident. AO 12C1 fracture type fixated with 14-hole APLS plate. Complicated with post-operative nerve palsy.
[17] and Dauwe [18] in 2020: Robinson [17] described a higher risk of axillary nerve injury during the insertion of straight plates with MIPO technique, while in a cadaveric study, Dauwe [18] showed a lower mean plate-bone distance with helical plates than with straight models, an indirect measure of lower risk of axillary nerve elongation.

Since 1996 Yang studied helical implants and in 2005, he reported results on the use of pre-contoured plates to treat comminuted fractures of the proximal and middle one-third of the humerus [10]. He observed satisfactory outcomes in terms of range of motion; however, it is unknown to what extent the action of twisting may weaken the plate and reduces the number of holes able to accommodate screws for proximal fixation [19]. In 1999, Gill and colleagues described a case of humeral nonunion associated with supraclavicular brachial plexus injury managed with a spiral compression plate to preserve the deltid muscle insertion, with the aim to promote successful recovery of the neurological affected upper limb [20].

Klepps in his cadaveric study showed that the detachment of more than one-fifth of the muscle may compromise the anterior deltoid, resulting in a partial abduction of more than one-fifth of the muscle may compromise the anterior deltoid, resulting in a partial abduction and forward elevation weakness. [7]. Helical plates have been introduced to overcome this disadvantage: in this design, the plate is twisted 90° to lie on the lateral aspect of the greater tuberosity and on the distal anterior side of the humeral shaft, with a parallel course along the radial nerve [9, 19]. In their biomechanical studies, Dell’Oca [9] and Krishna [19] showed other advantages: the gap closure at the fracture interface is better in helical plate fixation compared to straight plate fixation for all loading conditions; stress shielding is reduced due to the helical shape of the plate shifting the neutral axis into the bone; helical plates are more useful in spiral fractures since the implant absorbs the tensile stresses caused by torsion; finally, the screws in helical plates have different directions, providing more screw-holding power than in straight plates.

In 2012, Zhang et al. [5] used a lateral distal tubial helical plate to treat proximal and middle one-third humeral fractures: according to the Constant-Murley score (average value of 88), 28% of patients had excellent functional outcomes, and 64% had good results.

More recently, Moon and colleagues [11] used pre-contoured straight humeral plates via a MIPO approach in twelve patients; they underlined the difficulty for the surgeon of proper contouring to fit the humeral shape and suggested the need of dedicated helical plates to avoid damage to the holes locking treads. At the final follow-up, patients in their study showed a Constant-Murley score of 88.6 and a shoulder abduction of 153.7° on average.

Moreover, Wang [12] in 2018 analysed the use of 3D printed fracture models to fit the humeral shape accurately, and their patients reached a mean Constant score of 76 at one year of follow-up.

In 2021, Aguado and colleagues [21] used A.L.P.S helical plates with minimally invasive technique on fifteen patients: they observed functional results comparable with previous studies and a low risk of radial nerve injury. The multidirectional screws are a helpful instrument when a MIPO technique is employed.

The data observed in our study are in accordance with the aforementioned studies [5, 11, 12, 21]: as reported in the literature, the Constant score is influenced by the quality of the reduction in the greater tuberosity, the position of the screw and plate, patient age and post-operative physical therapy [5].

Additionally, satisfactory abduction and strength were established in all patients at clinical follow-up: this supports Da Silva’s results obtained by the comparison between straight and helical plates, with no statistical differences in the functional scores [22].

Further investigations with strength tests are advisable, in our opinion, to determine whether the deltoid preservation may induce clinical advantages.

We only had one case of iatrogenic radial nerve injury, a complication reported in the surgical treatment of middle third humeral fractures due to the extensive approach needed. Our suggestion is to identify and protect the nerve in those fractures with a distal diaphyseal extension (from 4 cm proximal to the fossa onward); nevertheless, the helical contouring allows an anterior fixation of the plate in the distal humerus, reducing the risk of nerve damage: this feature was confirmed in 2020 by Da Silva and colleagues [8], who had no cases of iatrogenic radial nerve injury using manually twisted plates in contrast to 6% incidence in the straight plate group, and by the other few studies that focused on helical locking plates [10–12].

In the patients with posttraumatic radial nerve palsy, we found the nerve trapped in the fracture site; neurological improvements were recorded within eight months after surgery.

Our study has some limitations. It is a retrospective study without a comparative group; there is a relatively small number of cases, which limits the reliability of our data: however, our results are in accordance with the current scarce literature that analyses dedicated helical plates.

Because of SARSCOV2 pandemic, we were unable to visit all patients in the clinic: in two cases, we performed a phone interview to complete Constant and DASH questionnaires. Nevertheless, we decided to collect information from both the patients and physiotherapists to record reliable data.

The strengths of our study are the involvement of two centres and the first clinical outcome study with only the Zimmer implant. The helical plate A.L.P.S (A.L.P.S. ® Proximal Humeral Plating System, Zimmer Biomet) does
not require contouring, and the presence of two different shapes of the proximal end of the plate reduces the risk of shoulder impingement.

Conclusions

In our experience, humeral helical plates may be an effective surgical alternative to conventional plates for managing complex proximal and middle one-third diaphyseal humeral fractures, given the biomechanical advantages, deltoid muscle insertion preservation, a better plate/bone congruency and a reduced risk of radial nerve palsy, while maintaining similar healing rates and functional outcomes.

Acknowledgements We would like to express our thank to Zimmer Biomet s.r.l, Italy for the technological support during the operative phase of the procedures.

Author’s contribution GN, Conceptualization Investigation Writing, VM, Investigation, NL, Conceptualization Project Administration Supervision, GP, Conceptualization Project Administration Supervision.

Funding No funding has been received for the study.

Declarations

Conflict of interest Authors declare that they have no conflict of interest.

Consent for publication Consent to publish was obtained from all individual participants included in the study, who agreed to participate to the study and approved having their data published.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study, who agreed to participate to the study and approved having their data published.

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