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New precontoured long locking plate for proximal metadiaphyseal fractures of the humerus: a cadaveric study for its use with the minimally invasive technique

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Background: The purpose of this study was to identify nerves at risk when using a minimally invasive plate osteosynthesis precontoured long proximal humerus locking plate and to evaluate the risk of injury to deltoid insertion and brachialis muscle.

Methods: Ten cadaveric upper limb specimens were used. A transdeltoid anterolateral approach was performed proximally and a second anterior approach was performed distally. A 14-hole “low” long precontoured ALPS locking plate (Biomet Trauma; Zimmer Biomet, Warsaw, IN, USA) was used. Subsequently, anatomic dissection to measure the anatomic relationship of the plate with the deltoid insertion, with the brachialis muscle, and with the axillary, radial, and musculocutaneous nerves was performed.

Results: The mean humeral length was 302 mm (standard deviation 52.3, 99% confidence interval: 259.3–344.6). In 6 specimens, the axillary nerve was located at the level of the third row of holes of the plate; in 3 specimens, at the level of the fourth row; and in one specimen, at the level of the second row. The distance between the plate and the musculocutaneous nerve was on average 10.2 mm (standard deviation 4, 99% confidence interval: 6.9–13.5) and between the plate and the radial nerve was on average 7.9 mm (standard deviation 4.7, 99% confidence interval: 4–11.8). The plate pierced the anterior distal fibers of the deltoid in all specimens. In 8 specimens, no brachialis muscle fibers were located under the plate.

Conclusions: The use of the long precontoured 14-hole ALPS locking plate with the minimally invasive plate osteosynthesis technique, previously identifying the axillary and musculocutaneous nerves, is feasible; however, the distances between the plate and the nerves remain low, so caution should be maintained. Despite the curved design of the plate, the deltoid insertion is partially compromised in all cases.

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Minimally invasive plate osteosynthesis (MIPO) for surgical treatment of humeral shaft fractures has gained popularity in recent years. Meta-analysis have shown advantages of MIPO plates over endomedullary nails in nonunion rates and over open reduction and internal fixation in iatrogenic neurologic injury rates.^{15,16} Compared with plate open reduction and internal fixation and endomedullary nails, the MIPO plate technique has also

shown better clinical outcomes with a lower rate of complications.⁶ Proximal metadiaphyseal fractures require long proximal humerus locking plates for stabilization making MIPO technique especially challenging in this area. Previous studies with MIPO technique in proximal metadiaphyseal fractures have used long straight or hand-contoured plates during surgery.^{10,14} Long straight plates risk radial nerve injury and manual contouring of the plate is technically difficult, imprecise, and can also damage the locking thread at the torsion point.³ New precontoured plates have been designed to avoid those problems and to prevent injury to the deltoid insertion. However, there are no published data regarding the potential neurologic risk and deltoid insertion injury when using these new precontoured long plates with MIPO technique.

Institutional review board approval was not required for this cadaveric study.

Conflicts of interest: The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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Figure 1 Right arm. Anterior view of the distal approach. Biceps brachialis retracted medially and musculocutaneous nerve exposed.



Figure 2 Periosteal raspatory elevator specially designed for MIPO technique.

The purpose of this cadaveric study is to identify nerve structures at risk when using a MIPO precontoured long proximal humerus locking plate and to evaluate potential injury to deltoid insertion and brachialis muscle.

Material and methods

Ten cadaveric upper limbs specimens were used. None of the specimens showed signs of previous surgeries or injuries. Skin marks were made on the lateral border and posterolateral corner of the acromion and lateral epicondyle. Total length of the humerus was measured between posterolateral corner of the acromion and lateral epicondyle. A transdeltoid 7-cm-long anterolateral approach was performed. With blunt dissection, the axillary nerve was routinely identified and protected. A distal approach was performed 5 cm proximal to the anterior fold of the elbow and 4-5 cm long. The intermuscular plane between the biceps and brachialis muscles was developed laterally, the biceps was retracted medially, and the musculocutaneous nerve was identified and protected (Fig. 1). A periosteal elevator specially designed for MIPO techniques was used to create a submuscular tunnel: the brachialis muscle fibers were split longitudinally from proximal to distal (Fig. 2). A 14-hole “low” long (227 mm) precontoured ALPS locking plate (Biomet Trauma; Zimmer Biomet, Warsaw, IN, USA) (Fig. 3) was introduced from proximal to distal (Fig. 4). The plate was positioned 2 cm distal to the upper border of the greater tuberosity as per manufacturing recommendation and fixed proximally with a Kirschner wire and distally with a cortical screw. Once the plate was fixed proximally and distally, the skin and subcutaneous tissue were removed, taking special consideration not to resect muscle tissue. Subsequently, anatomic dissection and measurement of the anatomic relationship of the plate with the deltoid insertion, with



Figure 3 Left 14-hole “low” long precontoured ALPS locking plate.

the brachialis muscle, and with the axillary, radial, and musculocutaneous (MC) nerves were performed. Specifically, we measured the distance between the lateral edge of the acromion



Figure 4 Right arm. Plate being introduced from proximal to distal approach.

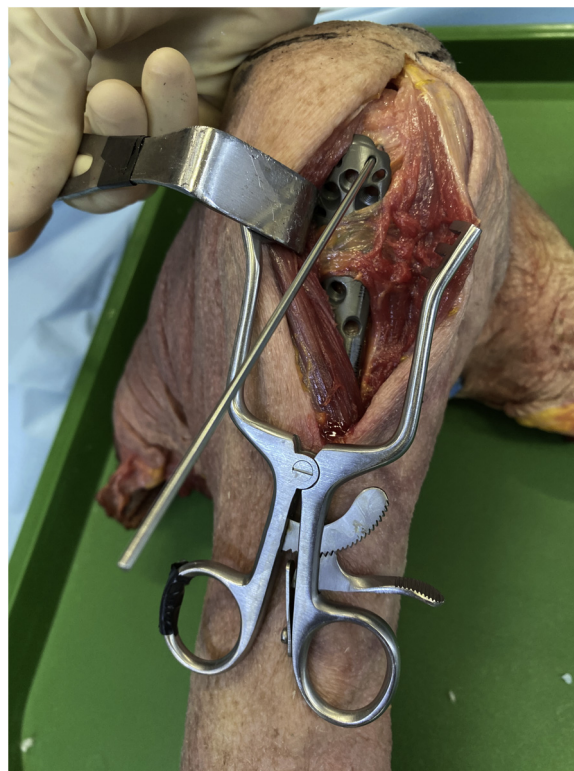


Figure 5 Right arm. Axillary nerve located at the level of the fourth row of holes in the plate.

and the axillary nerve, the location of the axillary nerve with respect to the holes in the plate, the relationship between the torsion point of the plate and the insertion of the deltoid, the closest distance between the MC and radial nerves to the plate and the presence or absence of brachialis muscle under the plate. To describe the relationship of the axillary nerve with the holes of the plate, these were arbitrarily divided into rows from proximal to distal. All measurements were made using a digital caliper with an accuracy of 0.1 mm.

Only descriptive statistics were performed, with measurements in metric units. Distances in millimeters are reported with their respective mean, standard deviation (SD), and 99% confidence intervals (CIs).

Results

The mean humeral length was 302 mm (SD 52.3, 99% CI: 259.3–344.6). The distance from the axillary nerve to the lateral edge of the acromion was 56.2 mm (SD 6.5, 99% CI: 50.9–61.5). In 6 specimens, the axillary nerve was located at the level of the third row of holes of the plate; in 3 specimens, at the level of the fourth row; and in 1 specimen, at the level of the second row (Fig. 5).

In the distal approach, the shortest distance between the plate and the musculocutaneous nerve was on average 10.2 mm (SD 4, 99% CI: 6.9–13.5), and it was at the level of the two most distal holes in the plate (Fig. 6). The distance between the point where the radial nerve pierces the lateral intermuscular septum and the lateral epicondyle was on average 117.7 mm (SD 7.9, 99% CI: 111.2–124.2). The shortest distance between the plate and the radial nerve was on average 7.9 mm (SD 4.7, 99% CI: 4–11.8), and it was found at the most distal aspect of the plate (Fig. 7).

In 9 specimens, the anterior curvature of the plate was located at the level of the deltoid insertion; however, in none of the



Figure 6 Left arm. Musculocutaneous nerve (*).

specimens it was located completely anterior. The plate pierced the anterior distal fibers of the deltoid in all specimens (Fig. 8).

In 8 specimens, no brachialis muscle fibers were located under the plate. In two specimens, some fibers of the brachialis muscle remained under the plate. In 1 specimen, a branch of the musculocutaneous nerve was trapped under the plate (Fig. 9).

Discussion

Our study reports the anatomic relationships of nerves potentially at risk of injury with the use of a new precontoured locking

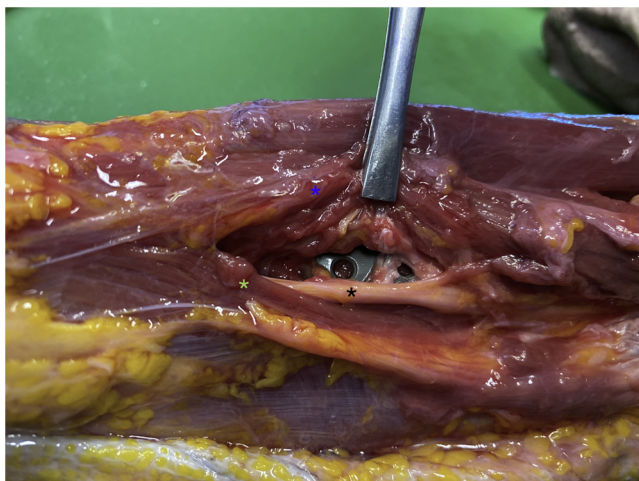


Figure 7 Left arm. Radial nerve (*), brachialis muscle (^), and brachioradialis muscle (^).

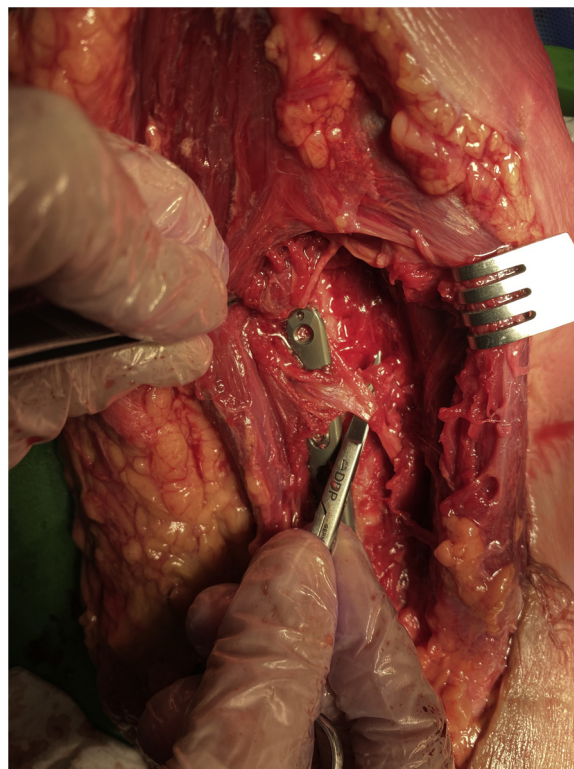


Figure 9 Left arm. Articular branch of the musculocutaneous nerve trapped under the plate.



Figure 8 Left arm. Distal deltoid muscle fibers anterior to the plate (*).

plate for proximal metadiaphyseal fractures of the humerus with MIPO technique.

The location of the axillary nerve with respect to the lateral edge of the acromion is relatively constant between 40 and 60 mm.^{4,9} Our results show values consistent with what has been published, with a mean of 56.2 mm. The anterolateral approach to the proximal humerus can be performed with or without identification of the neurovascular band of the axillary nerve and the posterior circumflex artery.^{10,12} However, regardless of the strategy of exploring or not the axillary nerve, we believe it is important to know its course with respect to the plate. The ALPS humerus locking plate has two variants, one named “high” plate, which is recommended to be fixed at 1 cm from the upper border of the

greater tuberosity and a “low” plate that should be located 2 cm from the upper border of the greater tuberosity. To simplify the study methodology, we arbitrarily decided to use only the “low” plate. By placing the plate 2 cm from the upper border of the greater tuberosity as recommended by the manufacturer, the course of the axillary nerve coincides in most cases with the third or fourth row of plate holes. Benninger and Meier² in a cadaveric study using the Proximal Humeral internal Locking System (PHILOS) plate (DePuy Synthes, Oberdorf, Switzerland) describe the course of the axillary nerve in relation to the segments called D and E of the plate that correspond to rows four and five of the plate. As per the manufacturer, it is recommended to place the PHILOS plate 1 cm below the upper border of the greater tuberosity, unlike the ALPS “low” plate, which must be located 2 cm distal to the greater tuberosity. This may explain the differences in the course of the axillary nerve with respect to the orifices of the plate between study by Benninger and Meier and ours. In addition, in a cadaveric study using a different proximal humerus plate placed through an anterolateral transdeltoid approach,⁴ the authors did not find a constant relationship between the course of the axillary nerve and the holes in the plate; however, the authors do not specify the exact location of the plate with respect to the greater tuberosity, which may explain the lack of correlation.

Several studies using an anterior MIPO plate highlight the importance of identifying and protecting the musculocutaneous nerve during the distal approach.^{1,7,8,13} Because the ALPS plate has an anteriorly precontoured curvature in its distal segment, identification of the MC nerve is important. The mean distance between the MC nerve and the plate in our study was 10.2 mm. Although the MC nerve was clearly identified in all the specimens in the interval between the biceps and brachialis muscle, in one of them, an articular branch of the MC was inadvertently trapped under the plate (Fig. 9). Using a manually molded helical plate, Gardner et al⁵

describe the risk zone for MC nerve injury at 13.5 cm (99% CI: 12.2–14.8 cm) from the superior border of the greater tuberosity. This distance is more proximal to that found in our study, probably because the ALPS plate in its distal segment is not strictly anterior but anterolateral, which brings it closer to the MC nerve in a more distal segment.

A long straight proximal humerus plate placed by the MIPO technique puts the radial nerve at risk. Benninger and Meier,² in a cadaveric study using the long PHILOS plate (DePuy Synthes, Oberdorf, Switzerland) in 8 specimens, describe entrapment of the radial nerve under the plate in 1 case. Precontoured plates avoid the radial nerve when it pierces the lateral intermuscular septum. Our results show, however, that the radial nerve is relatively close to the plate in its distal segment, at an average of 7.9 mm. In the distal MIPO approach, once the plane between the biceps and the brachialis muscle has been identified, it is recommended to perform a longitudinal split of the latter, which leaves a lateral muscle portion that protects the radial nerve. For this reason, a formal dissection of the radial nerve is not required. However, caution is necessary using lateral retractors in this area.

As per the manufacturer, the precontoured anterior curvature of the plate was designed to reduce the need to release the deltoid. However, our results show that despite the anterior curvature, the deltoid insertion is perforated and partially compromised in all cases. In the same cadaveric study cited previously, Benninger and Meier² used a long straight PHILOS plate (DePuy Synthes, Oberdorf, Switzerland) describing involvement of the central portion of the distal deltoid attachment. According to Sakoma et al.¹¹ who described the distal insertion of the deltoid in 7 portions, the most frequent compromise was the central portion, leaving the two most anterior and posterior portions intact. We did not perform detailed dissection of the different segments of the distal insertion of the deltoid; however, in all the specimens, deltoid fibers were found anterior to the plate. The clinical significance of this partial compromise of distal deltoid insertion is debatable and remains unclear. Because we performed a longitudinal split of the brachialis muscle, we did not find fibers of this muscle under the plate in 8 of 10 specimens. In two cases, some fibers were trapped under the plate.

There are few clinical studies with the use of proximal humerus plates with the MIPO technique for metadiaphyseal fractures of the proximal humerus. In a retrospective series of 29 patients, using the long straight PHILOS plate (DePuy Synthes, Oberdorf, Switzerland), Rancan et al did not report iatrogenic neurologic lesions. The surgical technique described was an anterolateral transdeltoid approach without dissection of the axillary nerve and a distal lateral approach identifying and protecting the radial nerve. Good clinical results and bone healing were obtained in 28 patients. Also in a retrospective case series, Touloupakis et al¹⁴ show the results of 11 patients using the long straight PHILOS plate with MIPO technique. The proximal approach was transdeltoid without axillary nerve dissection in 10 cases and deltopectoral in 1 case. The distal approach was indistinctly anterior or lateral, identifying the MC or radial nerve, respectively. The authors do not describe when a distal-anterior or distal-lateral approach was chosen. Postoperative radial nerve palsy was reported in 1 case. To our knowledge, there are no studies evaluating the risk of neurologic lesions using the ALPS plate with the MIPO technique for proximal metadiaphyseal humerus fractures.

Limitations

As in all cadaveric studies, intact humeri were used; therefore, the anatomic relationships are preserved. Under conditions of fracture with displacement and shortening of the segments, these

relationships may vary. The absence of muscle tone and retraction at the time of dissection can alter to some extent the anatomic relationships between the nerves and the plate.

Conclusions

The use of the long precontoured 14-hole ALPS locking plate with the MIPO technique, previously identifying the axillary and musculocutaneous nerves is feasible; however, the distances between the plate and the nerves remain low so caution should be maintained. Despite the curved design of the plate, the deltoid insertion is partially compromised in all cases.

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