Establishing the appropriate position of proximal humerus locking plates: a cadaveric study of five plating systems and their anatomic reference measurements

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Abstract

Background: The present study aimed to determine anatomic references for the placement of five proximal humerus locking plates.

Methods: Five proximal humerus locking-plate systems were placed on six human shoulder cadavers. Plates were positioned by fluoroscopic confirmation so that the inferior oblique screw was within 5 mm of the inferomedial cortex. Plate position was measured using the superior border of the pectoralis major tendon (PMT) to the bottom of the first slotted or nonlocking hole and top of the plate to the top of the greater tuberosity. The distance from the PMT insertion to the top of the humeral head was measured as a control.

Results: There was consistency within each plating system for both the distance from the PMT insertion to the first hole and the top of the plate to the greater tuberosity: Synthes first-generation [mean (SD) 13.7 mm (3.1 mm); 10 mm (1.3 mm)], Synthes second-generation [28.2 mm (2.2 mm); 18.5 mm (2.7 mm)], Biomet OptiLock[®] [25.5 mm (2.7 mm); 18.7 mm (2 mm)], Stryker AxSOS[®] [5 mm (2.8 mm); 12.3 mm (3.3 mm)] and Acumed Polarus[®] [9.5 mm (1.8 mm); 14.8 mm (1.6 mm)].

Conclusions: The present study provides measurements that improve the accuracy of plate positioning for five plating systems.

Keywords

anatomic landmarks, fracture, open reduction internal fixation, plate, proximal humerus, reference point

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Introduction

Open reduction internal fixation (ORIF) of two-, three- and four-part proximal humerus fractures has been shown to have better functional and subjective outcomes compared to hemi-arthroplasty (HA).^{1–5} Additionally, the use of pre-contoured locking plates for the treatment of these fractures has become increasingly popular. However, the complication rate from locking plate use for proximal humerus fractures remains high.^{6,7} A systematic review comparing ORIF, HA, and reverse total shoulder arthroplasty showed a significantly higher re-operation rate for ORIF.² Current trends also indicate that hemi-arthroplasty is falling out of favor to reverse total shoulder

arthroplasty, especially in older patients (> 65), while patients receiving ORIF remains unchanged in the Medicare population.⁸ Complications after ORIF using locked plates include: screw cut-out or penetration, varus collapse (e.g. loss of fixation), avascular necrosis, impingement and rotator cuff rupture.^{9–22}

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Increasing experience with the use of proximal humerus locking plates has shown that these complications can be reduced with certain surgical techniques.

Increasing the number of locking screws in the humeral head and appropriately placing angular locking screws to support the inferomedial cortex can reduce the incidence of varus collapse and subsequent screw penetration.^{23,24} These inferiorly placed locking screws, which support the medial calcar, reduce the rotational forces experienced by the bone-implant construct, particularly in the setting of medial comminution and initial varus displacement.^{24–28} The position of the locking screws is dictated by the position of the plate on the shaft; therefore, plate positioning is critical in reducing collapse or loss of reduction of the fracture. In addition, placement of plates too far proximal can lead to acromial impingement post-operatively.

The present study aimed to determine appropriate reference measurements for placement of proximal humerus locking plates with respect to the long axis of the humeral shaft and the superior border of the pectoralis major tendon (PMT). The distance from the superior border of the PMT insertion to the top of the humeral head has been established to have a consistent value of 5.6 cm. This relationship has been used reproducibly for assessing humeral height during shoulder hemiarthroplasty.^{29,30} To date, no study has evaluated the PMT as an anatomic landmark for appropriate locking plate positioning during reduction and fixation of proximal humerus fractures. Therefore, our hypothesis was that the superior border of the PMT can be used as a reference point for obtaining appropriate locking plate height on the proximal humerus, especially during placement of the inferomedial screw. Determining reference measurements for proper plate position may help surgeons with intra-operative reduction and fixation, and can potentially help reduce the incidence of failure secondary to technical error.

Materials and methods

After institutional approval for the use of cadaveric human specimens, six fresh-frozen human shoulder cadavers were obtained. There were three left and right shoulders from four males and two females. Proximal humerus locking plates were obtained from multiple vendors for research purposes. We obtained Synthes first- and second-generation, Biomet OptiLock® (Warsaw, Indiana, USA), Stryker AxSOS® (Mahwah, New Jersey, USA) and Acumed Polarus® (Hillsboro, Oregon, USA) proximal humerus anatomic locking plate systems. The Synthes first-generation plate differs from the second-generation plate in that it is not a side-specific pre-contoured plate like the second-generation plate.

Each of the five unique locking plates were placed on each of the six proximal humerus cadavers. We determined that the plate position was appropriate by confirming on fluoroscopy that the inferior oblique screw was within 5 mm of the inferior medial cortex of the humeral head (Fig. 1). Gross anatomic measurements were then performed. First, we measured the distance from the superior border of the PMT to the superior most aspect of the humeral head as described previously (Fig. 2a).^{29,30} Then, we measured the distance from the superior border of the PMT to the inferior edge of the first slotted hole (Fig. 2b, c) or proximal nonlocking hole if no slotted hole was present on the implant. Next, the distance from the superior edge of the plate to the superior edge of the greater tuberosity was measured (Fig. 2b, c). All distances were measured using calipers. Basic statistical means were made from the plate measurements on each cadaver specimen.

Results

The mean (SD) distance from the superior border of the PMT to the top of the humeral head was 5.6 cm (0.1) cm (Table 1). The mean distances from the superior border of the PMT to the inferior edge of the first slotted or nonlocking 1 hole and from the top of the plate to the superior edge of the greater tuberosity are shown in Table 2 for all plating systems. Although the distances were unique for each plating system, they were consistent across all anatomic specimens.

Figure 1. Fluoroscopic confirmation of appropriate locking plate position on cadaveric shoulder. The white line highlights the inferomedial calcar screw with the distance between the screw and inferior cortex measured at 5 mm.

Figure 2. Cadaveric measurements of reference points. Two views of the human cadaveric shoulder dissected showing the pectoralis major tendon (*) and the distance (white double-arrow) measured to the top of the humeral head (a). The second (b) and third (c) cadaveric views show the cadaveric shoulder after the placement of the locking plates with the distance (white double-arrow) from the pectoralis major tendon (*) to the inferior most portion of the slotted hole (horizontal white line) and the distance (white double-arrow) from the top of the locking plate to the top of the greater tuberosity. PMT, pectoralis major tendon; GT, greater tuberosity.

Table 1. Distance from the superior border of the pectoralis major tendon (PMT) to the top of the humeral head.

Shoulder	PMT to humeral head (cm)
1	5.7
2	5.8
3	5.6
4	5.4
5	5.7
6	5.6
Mean (SD)	5.6 (0.1)

Discussion

The use of locking plate technology for proximal humeral fracture fixation has increased over the last 10 years.³¹ However, the reported complication rate has ranged from 14% to 40% after the use of locking plates.^{9–22} The most common complications are screw penetration and varus collapse of the head,^{9,16,20} with mechanical support of the inferomedial cortex being an important factor for maintaining reduction after plating.²⁴ Therefore, achieving correct plate height intra-operatively to support the medial calcar with fixed angle screws can help minimize the chances for collapse or subsidence of the head. Also, a better knowledge of adequate plate position can prevent intra-operative

delays caused by plate re-positioning or inadequate screw position. However, the challenge for orthopaedic surgeons is that not all plates are designed identically, and an understanding of this variability is important, especially for screw trajectory and plate positioning.

In the present study, we aimed to determine anatomic reference measurements for five different locking plates used for proximal humerus ORIF. We used the PMT, which is a previously described anatomic reference point for establishing height in HA cases, and the relationship of the plate to the greater tuberosity as our landmarks. No study to date has analyzed the relationship of the PMT with respect to appropriate locking plate positioning for fixation of proximal humerus fractures.

Murachovsky et al.²⁹ and Torrens et al.³⁰ reported a reproducible mean distance of 5.6 cm from the superior border of the PMT to the top of the humeral head in their anatomic studies for establishing humeral length during shoulder hemiarthroplasty. In a recent study by Ponce et al.²⁸, further analysis was performed based on anatomic variations of patient sex and height, and this correlated a 1.7 mm increase in PMT for every 10 mm increase in patient height over 1.7 m.²⁸ Their mean measured distance from the superior border of the PMT to the top of the humeral head was 5.9 cm for men and was 5.5 cm for women.²⁸

In the present study, our hypothesis was supportive of PMT being used as a reference point to obtain an appropriate plate height for placement of the oblique inferomedial screw during plating of proximal humerus fractures. The variability that we measured across the plating systems is important to highlight because surgeons should become familiar with the unique

Table 2. Anatomic reference measurements for five proximal humerus plating systems.

	Synthes First-generation	Synthes Second-generation	Biomet Optilock®	Stryker AxSOS®	Acumed Polarus®
PMT to first slotted/ NL hole (mm)	13.7 (3.1)	28.2 (2.2)	25.5 (2.7)	5 (2.8)	9.5 (1.8)
Plate edge to GT (mm)	10 (1.3)	18.5 (2.7)	18.7 (2)	12.3 (3.3)	14.8 (1.6)

The distances of the superior border of the pectoralis major tendon (PMT) to the inferior edge of the first slotted or proximal nonlocking hole and superior edge of plate to the superior most edge of the greater tuberosity are listed above. NL, nonlocking; GT, greater tuberosity. Data are the mean (SD).

geometry, number of proximal locking holes, and the different options and location of where the oblique inferomedial screw can be placed. For example, the difference between the second-generation Synthes locking plate and Stryker AxSOS® with respect to distance from the superior border of the PMT to the first-slotted or nonlocking hole was 23 mm. However, the overall difference between plates for the distance from the superior edge of the plate to the top of the greater tuberosity did not show as much variability.

The limitations of the present study include it being a cadaveric study with an intact proximal humerus. We did not create a fracture model with subsequent reduction with the plates to recreate injury patterns. The concept of using the measurements determined in the present study to help with intra-operative plate positioning mandate that the fracture reduction be near anatomic; specifically, that the fracture has been disimpacted to restore native length. In this way, we also feel that this can help intra-operative judgment of the fracture reduction. We attempted to include a wide breadth of implants from major vendors, although we were not able to include all representations.

The present study provides a series of reference measurements for five unique proximal humerus plates which we consider will be useful for referencing by orthopaedic surgeons. Familiarity with these reference measurements can help with the more accurate positioning of plates during fixation, which may allow for a better judgment of fracture reduction. Based on our data, the superior border of the PMT can also be reliable landmark for establishing humeral and plate height during fixation of proximal humerus fractures.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: J. A. G. receives consulting fees from Acumed and Stryker, which are unrelated to the creation of this manuscript.

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Ethical review and patient consent

No patients were enrolled for this study. Anatomic research approval was obtained for all cadavers used in this study..

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