The Relationship Between Patient Demographics, Anatomic Humeral Measurements, and Placement of a Locking Plate that Achieves Recommended Screw Fixation in the Treatment of Proximal Humerus Fractures

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Introduction

- For displaced and complex proximal humerus fractures, open reduction internal fixation (ORIF) with plates is one of the pervading modalities of surgical treatments
- Studies have shown the pivotal role of the medial support with calcar screws in improving fixation
- The calcar screw, however, is commonly misplaced when using fixed angle plates

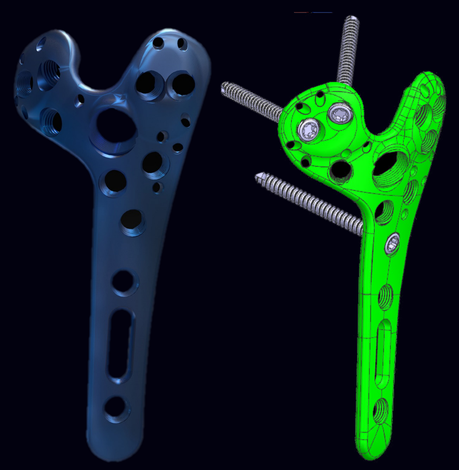


Figure 1. Proximal humerus fracture locking plate (Equinoxe PHx Victory Plate; Exactech Inc.) (left) and two screws on lesser tuberosity branch and calcar screw (right)

Objective

- Develop a reliable methodology for guiding plate placement that achieves satisfactory calcar (and central, if applicable) screw placement(s) across a wide range of humeral anatomies

Methods

- Thirty cadaveric humeri were virtually implanted with a proximal humerus fracture locking plate (Equinoxe PHx Victory Plate)
- Implantation constraints/assumptions driving final plate placement:
  1. Small plates for females and large plates for males
  2. Central screw passes through center of rotation
  3. Designated screw reaches calcar region
  4. Bicipital groove sits between two superior screws on lesser tuberosity branch of plate
- Post-implantation, distances between the top of the plate and landmarks of interest were measured in the AP view (see Figure 2 for definitions)
- Demographics were compared between the males and females using Welch's t-test, with significance set at $p < 0.05$
- Pearson correlations between demographics/anatomic variables and plate placement variables were calculated, with linear regressions for the strongest correlations (>0.8)

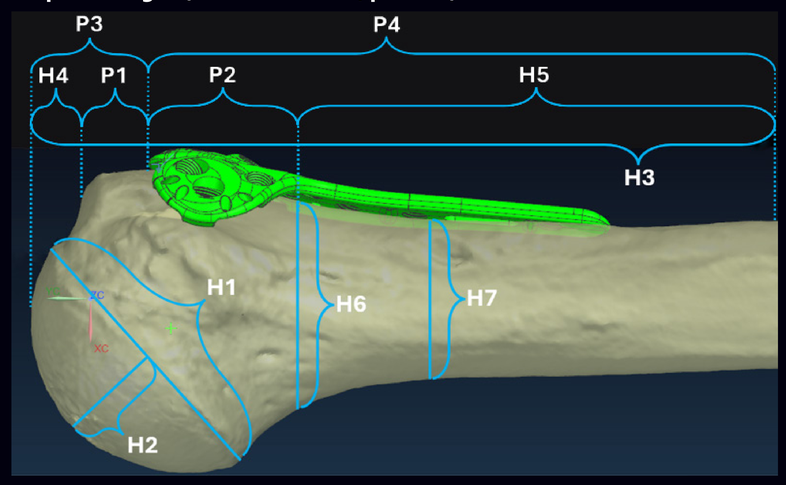
Results

- Thirty cadaveric specimens (15 males and 15 females), with an average age, height, weight, and BMI of 78 years, 169 cm, 64 kg, and 23, respectively, were included in this study
- No significant differences in demographics between males and females, except for height (176cm vs. 161cm, p=0.011)

Figure 2. Anatomic (H) and plate placement (P) variable definitions:

H1 –Humeral Head (HH) diameter
H2 – HH thickness
H3 – HH to Deltoid Tuberosity (DT)
H4 – HH to Greater Tuberosity (GT)
H5 – Surgical Neck (SN) to DT
H6 – SN diameter
H7 – Diaphyseal diameter at halfway point between HH and DT

P1 – GT to Plate
P2 – Plate to SN
P3 – HH to Plate
P4 – Plate to DT



- Strongest correlations between (Table 1 and Table 2):
  - P4 to H5 (R=0.98, p-value<0.001)
  - P4 to H3 (R=0.95, p-value<0.001)
  - P3 to H7 (R=0.91, p-value<0.001)
  - P3 to H1 (R=0.90, p-value<0.001)
- Other notable pairs (Table 1):
  - P3 to H2 (R=0.79, p-value<0.001)
  - P3 to sex (R=-0.78, p-value<0.001)
  - P3 to H6 (R=0.73, p-value<0.001)

Table 1. Pearson correlation coefficients between pairs of anatomic and plate placement variables

		Anatomic Variables											
		Sex	Age	Height	Weight	BMI	H1	H2	H3	H4	H5	H6	H7
Plate Placement Variables	P1	-0.71	-0.22	0.61	0.25	-0.25	0.72	0.61	0.42	-0.20	0.09	0.47	0.68
	P2	-0.31	0.16	0.08	-0.09	-0.08	0.42	0.40	-0.15	-0.20	-0.47	-0.30	0.11
	P3	-0.78	-0.38	0.52	0.53	0.03	***0.90***	0.79	0.63	0.49	0.27	0.73	***0.91***
	P4	-0.29	-0.25	0.30	0.53	0.14	0.28	0.31	***0.95***	0.26	***0.98***	0.60	0.32

Table 2. Linear regression model summaries for strongest pairs of anatomic and plate placement variables

Variables	Regression Equation	Standard Error	R-sq	p-value
P4 to H5	P4(mm) = 37.15 + 0.9041 H5(mm)	1.81703	96.09%	**<0.001**
P4 to H3	P4(mm) = 13.26 + 0.7821 H3(mm)	2.98927	89.43%	**<0.001**
P3 to H7	P3(mm) = - 6.890 + 0.9915 H7(mm)	1.63374	81.97%	**<0.001**
P3 to H1	P3(mm) = - 20.82 + 0.8089 H1(mm)	1.70248	80.42%	**<0.001**

Discussion & Significance

- Surgeons typically aim to position the plate relative to the top of the humeral head (P3) or greater tuberosity (P1), and although this study did find strong correlations between those plate placement variables and anatomic measurements, there were stronger correlations between other pairs
- There exists a tradeoff between model accuracy and practicality of anatomic landmarks involved
- Highest correlations occurred when using the DT as a reference landmark (i.e., P4 to H5; P4 to H3), but that landmark may not be as accessible as other, more proximal landmarks
- On the other hand, using the top of the HH as a reference landmark also resulted in high correlations (i.e., P3 to H7; P3 to H1), but the complexity of fracture and quality of provisional reduction could impact final plate placement
- Considering the surgical workflow, there were other correlations that, albeit weaker, may still be relevant (i.e., P3 to sex; P3 to H6)
  - Using patient sex or SN diameter to determine plate placement as a function of the distance between the plate and the top of the HH may help streamline the surgical workflow, as they are known, can be measured on pre- or intra-operative imaging, or can be translated to physical intra-operative measurements
- Limitations of this study include:
  - Relatively small sample size
  - Lack of consideration for other rationales on implantation methods that prioritize different constraints (e.g., best fit for tuberosities, avoid impingement with acromion during elevation, etc.)
  - Usage of intact humeri, as opposed to fractured humeri (fracture complexity/ provisional reduction could impact the distance measurements)

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