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Three-dimensional morphometry of the proximal ulna: a comparison to currently used anatomically preshaped ulna plates

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Background: Anatomically preshaped plates are increasingly used for stabilization of comminuted olecranon and Monteggia fractures. The purposes of this study were to investigate the morphology of the proximal ulna and to compare morphologic findings with geometry of 4 preshaped ulna plates.
Materials and methods: Forty human elbows (mean age, 68 years; range, 21-98 years) were measured by 2 independent observers using 64-slice computed tomography scans and 3-dimensional measuring software.
Results: Measurements showed a mean dorsal hook angle of 95.3° ± 9.0° (range, 74.7°-110.8°) with gender-specific differences (mean, 92.2° ± 8.1° in men and 98.3° ± 8.9° in women; $P = .029$); a mean distance from the tip of the olecranon to the proximal edge of the ulna of 24.7 ± 2.7 mm (range, 20-30.5 mm) with gender-specific differences ($P = .00068$); a mean varus angulation of 14.3° ± 3.6° (range, 5.8°-21.2°); and a mean anterior angulation (proximal ulna dorsal angulation) of 6.2° ± 2.7° (range, 1.0°-11.2°). The investigated plates offered a tolerable (± standard deviation) hook angle in 25% to 68%, an appropriate varus angulation in 0% to 20%, and an adequate anterior angulation in 23% to 88%. The intraclass correlation coefficient was between 0.74 and 0.91.
Conclusion: The proximal ulna has a gender-specific and variable morphology. Some currently used anatomically preshaped proximal ulna plates differ significantly from these morphologic findings. In cases where reduction is not exactly possible, application of an ‘‘anatomically preshaped’’ plate may result in poor reduction. Especially in case of Monteggia fractures with instability of the radiocapitellar joint, surgeons could be misguided by plates that do not incorporate anterior angulation, resulting in subluxation of the radial head on the capitellum.
Level of evidence: Basic Science Study, Anatomic Study, Imaging Study.

Keywords: Preshaped ulna plates; morphometry of proximal ulna; Monteggia fracture

Comminuted fractures of the proximal ulna and Monteggia fractures are commonly treated by plating osteosynthesis.[1,4,9,10] The prerequisites for achieving satisfactory functional results are anatomic fracture reduction and stable internal fixation.[2,7,8]

This is a University of Graz Ethical Committee approved study that formed part of a Diploma thesis. It was noted as not being a clinical study.

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In recent years, anatomically preshaped plates have become increasingly available and sold by industry. Using these preshaped plates in daily clinical practice has shown that, on many occasions, these plates do not fit the proximal ulna as promised by the term ‘‘anatomically preshaped plate.’’ The reason for this discrepancy may be variable anatomy of the proximal ulna. A review of the literature showed a paucity of published articles about the ulna’s morphologic variations—especially with regard to the hook angle, varus angulation, and anterior deviation of the proximal ulna.[5,11,13-15] The term ‘‘hook angle’’ describes the angle between the proximal plane of the ulna from the tip to the triceps insertion area and the dorsal plane distal from the triceps insertion area. Anterior angulation of the proximal ulna is diametrically described as proximal ulna dorsal angulation (PUDA) by some authors, meaning the same dorsal ‘‘apex’’ of the proximal ulna.[11]

The purposes of this human morphologic study were (1) to investigate the 3-dimensional (3D) morphometry of the proximal ulna (dorsal hook angle and anterior and varus angulation) by use of high-resolution computed tomography (CT) scans and 3D reconstruction software and (2) to compare the anatomic/morphologic findings with the geometry of 4 clinically used preshaped proximal ulna plates.

Materials and methods

Type of study

In this anatomic study, we investigated the morphometry of human ulnae by measuring 6 different distances and 3 different angles and comparing the study results with 4 anatomically preshaped olecranon plates.

Population selection

Forty human elbows were included in this study. We used 30 cadaveric elbows, preserved according to the embalming method of Thiel.[12] To increase the number of subjects and include younger patients, we included 10 adequate CT scans of patients treated in our hospital during the last few years with radial head fractures. Elbows with severe arthrosis, radiologic evidence of trauma to the ulna, or other observable pathologic changes were excluded from this study.

Radiologic method

The osseous anatomy of the elbows was digitized in the supine position with a 64-slice Siemens SOMATOM Sensation CT system (0.6-mm contiguous axial slices; Siemens Medical Solutions, Malvern, PA, USA). DICOM (Digital Imaging and Communications in Medicine) raw data sets were reconstructed by use of the 3D software program MIMICS (Materialise, Leuven, Belgium) (Figs. 1 and 2).

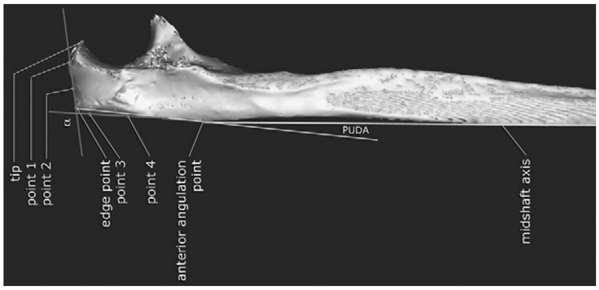

Figure 1 Three-dimensionally reconstructed right elbow in a male patient showing measurement points, hook angle (α), and anterior angulation of the whole shaft.

Morphologic measurements

For all measurements after 3D reconstruction, the first reference point for measurements of the olecranon morphology was set at the middle of the proximal surface of the semilunar notch (‘‘tip’’ of the olecranon). By setting additional measurement points at the middle of the proximal plane of the olecranon (point 1 at 7 mm and point 2 at 17 mm distal to the tip of the olecranon) and 2 further points along the shaft (point 3 at 5 mm and point 4 at 20 mm distal to the ‘‘edge’’ point), the angle of the hook was calculated (α in Fig. 1). The mediolateral width of the proximal ulna was measured at 3 levels: level 1, triceps insertion; level 2, proximal ulnar shaft (20 mm distal to the edge point), and level 3, midshaft of the ulna (80 mm below the edge point). The angulation of the proximal and middle ulnae in the frontal and sagittal planes (varus and anterior deviation) was measured in the 3D reconstructed mode. The varus angulation was measured between the axis of the olecranon (line defined by points 3 and 4) and the ulna midshaft axis as presented in Figure 2. The anterior angulation (PUDA) was given similarly between these 2 lines in the lateral view (Fig. 1). The point of rotation for the varus and anterior angulation was defined, and the distances between these 2 points and the edge point were measured.

The accuracy of this technique was limited by the resolution of the CT scans with ±0.5 mm for all measured dimensions.

Plates used for comparison

Four locally distributed and commonly used preshaped olecranon/proximal ulna plates were analyzed by use of data provided by the manufacturers or measured with a goniometer 3 times (hook angle for plate C - longest plate, anterior angulation for plate A - longest plate) (Table I):

Plate A was the LCP Olecranon Plate (6 different lengths from 86-216 mm, left/right plates; Synthes, Solothurn, Switzerland).
Plate B was the PERILOC Olecranon Locking Plate (5 lengths from 56-157 mm, left/right plates; Smith & Nephew, London, England).
Plate C was the Olecranon Plate (4 different lengths, no chirality; ITS GmbH, Lassnitzhöhe, Austria).
Plate D was the Acumed Olecranon Plate (5 lengths for standard plate and 2 lengths for extended plate, left/right plates; Acumed, Hillsboro, OR, USA).