Quantitative 3-Dimensional Computed Tomography Measurements of Coronoid Fractures

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Purpose Using quantitative 3-dimensional computed tomography (Q3DCT) modeling, we tested the null hypothesis that there was no difference in fracture fragment volume, articular surface involvement, and number of fracture fragments between coronoid fracture types and patterns of traumatic elbow instability.

Methods We studied 82 patients with a computed tomography scan of a coronoid fracture using Q3DCT modeling. Fracture fragments were identified and fragment volume and articular surface involvement were measured within fracture types and injury patterns. Kruskal−Wallis test was used to evaluate the Q3DCT data of the coronoid fractures.

Results Fractures of the coronoid tip (n = 45) were less fragmented and had the smallest fragment volume and articular surface area involvement compared with anteromedial facet fractures (n = 20) and base fractures (n = 17). Anteromedial facet and base fractures were more fragmented than tip fractures, and base fractures had the largest fragment volume and articular surface area involvement compared with tip and anteromedial facet fractures. We found similar differences between fracture types described by Regan and Morrey. Furthermore, fractures associated with terrible triad fracture dislocation (n = 42) had the smallest fragment volume, and fractures associated with olecranon fracture dislocations (n = 17) had the largest fragment volume and articular surface area involvement compared with the other injury patterns.

Conclusions Analyzing fractures of the coronoid using Q3DCT modeling demonstrated that fracture fragment characteristics differ significantly between fracture types and injury patterns. Detailed knowledge of fracture characteristics and their association with specific patterns of traumatic elbow instability may assist decision making and preoperative planning.

Clinical relevance Quantitative 3DCT modeling can provide a more detailed understanding of fracture morphology, which might guide decision making and implant development. *(J Hand Surg Am. 2015;40(3):526−533. Copyright © 2015 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Coronoid, fracture, morphology, computed tomography, 3-dimensional.

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Regan and Morrey[1] classified fractures by size, but the Mayo classification as described by O'Driscoll et al[2] seems more useful because each type of coronoid fracture is associated with specific patterns of traumatic elbow instability.[3] There are associations between small transverse tip fractures and terrible triad injuries, between anteromedial facet fractures and varus posteromedial rotational instability injuries, and between larger basal fractures of the coronoid process and anterior and posterior olecranon fracture dislocations.[3−5]

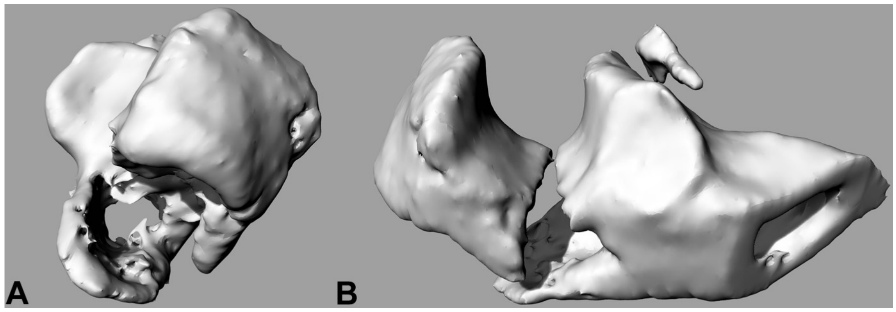

FIGURE 1: Three-dimensional polygon mesh reconstruction of an intra-articular posterior Monteggia injury associated with terrible triad fracture dislocation of the elbow. **A** Front view. **B** Lateral view.

Quantitative 3-dimensional computed tomography (Q3DCT) modeling technique is useful for measuring fracture fragment volume and articular surface area[6] and helps to determine articular characteristics (eg, size, shape, articular surface area).[6–9] The Q3DCT data can provide a more detailed understanding of fracture morphology, which might guide decision making and implant development.

The purpose of this study was to analyze fractures of the coronoid using Q3DCT modeling technique. We tested the null hypothesis that (1) there was no difference in fracture fragment volume, articular surface involvement, and number of fracture fragments between different fracture types according to the Mayo classification; 2) there was no difference in fracture fragment volume, articular surface involvement, and number of fracture fragments between different fracture types according to the classification of Regan and Morrey[1]; and (3) there was no difference in fracture fragment volume, articular surface involvement, and number of fracture fragments among different injury patterns (terrible triad fracture-dislocation, varus posteromedial rotational instability pattern, olecranon fracture dislocation, and posterior Monteggia injury associated with terrible triad fracture dislocation).

MATERIALS AND METHODS

Subjects

After our institutional review board approved the study, we performed a retrospective search of our billing data to identify patients with a coronoid fracture between July 2001 and January 2014 at 2 level I trauma centers. International Classification of Diseases, Ninth Revision, Clinical Modification codes (813.0x for closed fracture and 813.1x for open fracture) and Current Procedural Terminology codes (24586−24685, including elbow dislocations, Monteggia type of fractures, and radial and ulnar fractures) were used to search the billing data. We found 207 patients with coronoid fractures. Inclusion criteria were patients aged 18 years or more with an acute fracture of the coronoid and a computed tomography (CT) scan with slice thickness of 1.25 mm or less displaying the complete fracture. A total of 89 patients met the inclusion criteria. We excluded 7 patients with low-quality CT images or artifacts. There were no major differences between these patients and the 82 we included.

Quantitative 3-dimensional CT

We obtained the original Digital Imaging and Communications in Medicine files of selected CT scans through the Picture Archiving Communications System database of the 2 hospitals. All CT scans had a slide thickness between 0.625 and 1.25 mm. The Digital Imaging and Communications in Medicine files were loaded into 3D Slicer (Boston, MA), a software program used for analysis and visualization of medical images. Bony structures were manually marked on transverse, sagittal, and oblique CT slides using the PaintEffect and additional Threshold Paint option available in this program. Voxels within the predefined threshold range (225.00−1760.00 Hounsfield units) were labeled and annotated as bone. After marking all cortical bony structures, including fracture fragments, of the proximal ulna on each CT cut, we created 3-dimensional polygon mesh reconstructions (Fig. 1).

The 3-dimensional mesh reconstructions were imported into Rhinoceros (McNeel, Seattle, WA) for further analyses. The volume of coronoid fracture fragments was measured using the standard volume command in Rhinoceros. Subsequently, the articular surface area was marked with a polyline on the mesh reconstructions and measured using the Area command after splitting the mesh surface with the applied polyline. To calculate the total articular surface area