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ORIGINAL STUDY

Morphological characteristics of olecranon fractures in adults : a Computed Tomography-based study

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The aim of this study was to identify the fragment's shape by evaluating olecranon fractures. We examined the CT images of 48 olecranon fractures (28 women and 20 men). Mean age was 59.9 years. On the olecranon's posterior surface, we measured the distance between the apex of the olecranon fragment and the radial edge of the flat spot on the short axis and the width of the flat spot on the same short axis. The tip radial ratio (i.e., the tip radial edge to the flat spot width) was derived from these parameters. The mean tip radial edge was 1.96 mm, and the flat spot width was 12.64 mm ; therefore, the tip radial ratio was 0.15 mm. Radial inclination on the articular surface was 30.55°. Our findings confirmed our hypothesis that the fracture lines run from the proximal ulnar side to the distal radial side on the olecranon's posterior and articular surfaces.

Keywords : olecranon fracture ; anatomy ; fracture pattern ; elbow fracture ; radiographic study ; retrospective study ; intra-articular olecranon fractures ; apex distance ; olecranon fragment ; morphological characteristics.

INTRODUCTION

Although plate fixation devices for olecranon fractures are strong and reliable, they have high rates of soft tissue irritation and often require hardware removal (*2,6,11,13*). The olecranon is directly covered by a bursa (i.e., subcutaneous tissue and skin). This makes access to the fracture site easy ; however, the plate, especially when set posteriorly, must be located subcutaneously (*11,13*). In addition, the triceps tendon exists on top of the olecranon, which prevents surgeons from setting the plate directly on the olecranon (*8*). Thus, wound dehiscence at the tip of the olecranon is not an uncommon complication, and various flaps have been used for treating such soft tissue defects (*5,8*).

To adequately set the plate on the olecranon, surgeons should consider the type of olecranon fracture and its anatomical characteristics. However, the

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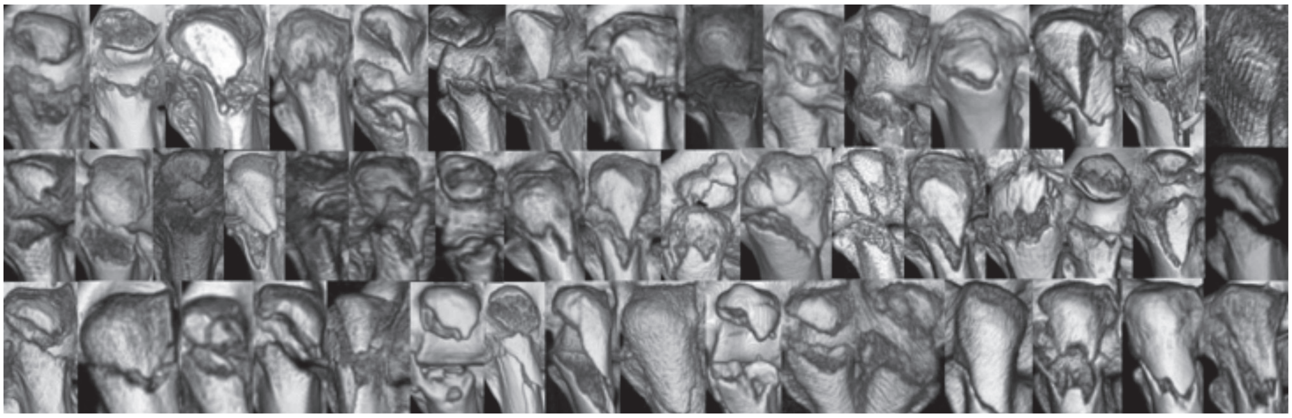

Fig. 1

proximal ulna has wide variations, making it difficult to determine the fracture type (*16*). In addition, only a few reports are available on the characteristics of the fractured olecranon. In our clinical experience, the fracture lines run from the proximal ulnar side to the distal radial side on the olecranon's posterior and articular surfaces (Fig. 1).

The purposes of this study, which was approved by the appropriate ethic review board, were 1) to evaluate the patients' original CT images of the olecranon fracture and 2) to prove our hypothesis that the fracture lines run from the proximal ulnar side to the distal radial side on the olecranon's posterior and articular surfaces (Fig. 2).

PATIENTS AND METHODS

We retrospectively reviewed 52 cases of olecranon fractures treated at our hospital between 1 April 2007 and 30 May 2014 and evaluated them using CT scans. We excluded four fractures, because three of them were avulsion fractures and the remaining one had bony spurs, which interfered with the radiological assessments. Thus, we included 48 olecranon fractures, and there were no open fractures.

The three-dimensional-CT volume data was rendered, reconstructed, and analysed using the Aquarius Net Thin Client (TeraRecon, Foster City, CA, USA). We did not evaluate the fractured fragment itself. Instead, we evaluated the distal diaphyseal side of the proximal ulna.

On the proximal ulna, the posterior side of the olecranon is a broad flat surface, which narrows progressively from the proximal to the distal ends ; the surface finally ends in a line at the posterior border (*3,18*). To define the plane, including the flat spot, we selected three points of intersection : the point at the fracture line and at the radial edge and ulnar edge of the flat spot ; the point of rotation for anterior angulation from the lateral view ; and the centre of the posterior border from the posterior-anterior view. Then we determined a longitudinal mid-bisecting line of the proximal ulnar long axis line, as described by Puchwein *et al*, and a short axis line on the plane described above (*11*) (Fig. 3).

We measured the distance between the apex of the olecranon fragment and the radial edge of the flat spot on the short axis (i.e. the tip radial edge) as well as the width of the flat spot on the same short axis (i.e. the flat spot width) (Fig. 4). Additionally, the tip radial ratio (i.e. the tip radial edge to the flat spot width) was derived from these parameters.

The flat spot plane migrated vertically to the articular surface. Therefore, radial inclination on the articular surface was defined between the short axis and the fracture line on the plane (Fig. 5).

Finally, we defined a plane perpendicular to the flat spot plane and included the tip point of the olecranon fragment. In this plane, we measured the angle between the flat spot plane and the fracture line from the articular surface to the dorsal surface (i.e. the lateral fracture line angle) (Fig. 6).

To ensure the reliability of the measurements, two orthopaedic surgeons were blinded to each other's results.

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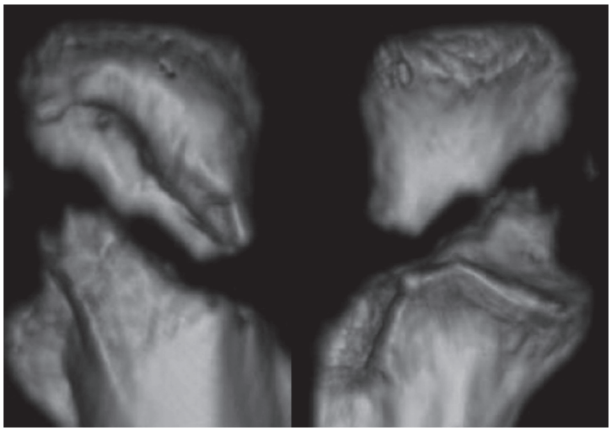
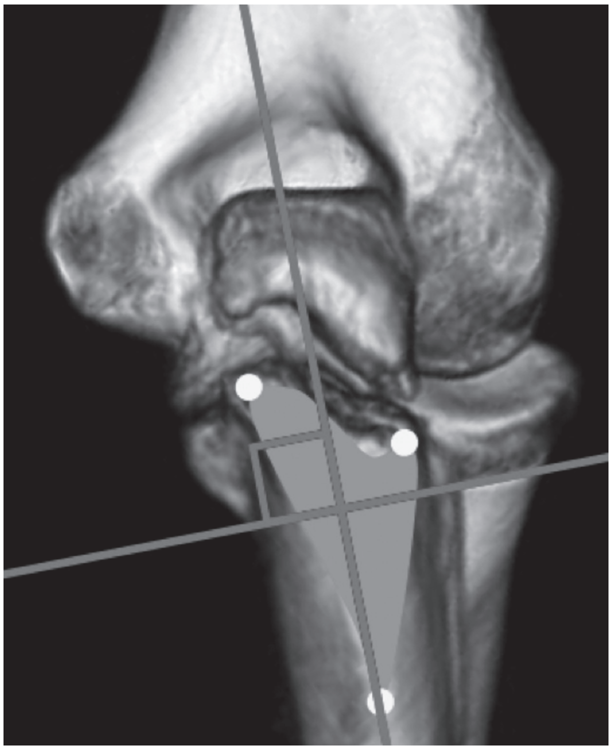


Fig. 2



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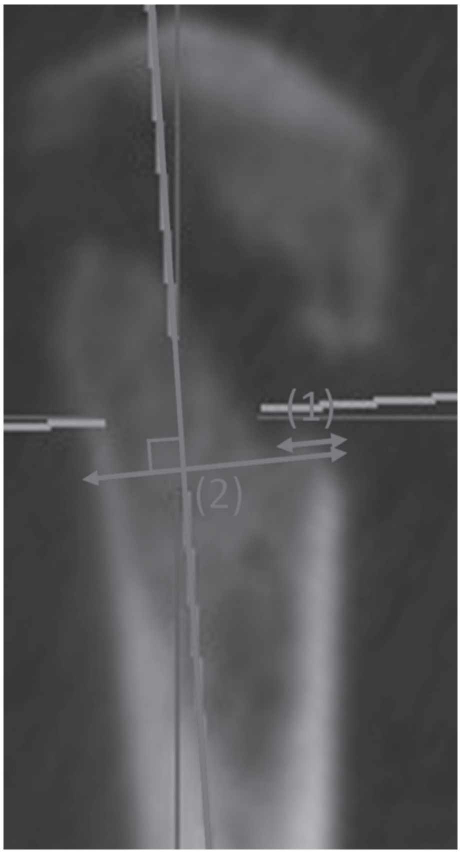

Fig. 4

All radiographs were examined twice. The images were re-examined > 1 week after the first examination, and the mean value of the four series of data was accepted.

Values were reported as the mean ± standard deviation (minimum, maximum) for the tip radial edge, flat spot width, tip radial ratio, radial inclination on the articular surface, and lateral fracture line angle. The interclass correlation coefficients and the Cronbach's alpha coefficients were calculated to assess reliability. All analyses were performed using SPSS for Windows, version 21.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

There were 28 women and 20 men with a mean age of 59.9 years (range, 18-101 years). Motor vehicle and bicycle crashes accounted for the largest number of fractures (n = 21), and falls from a standing height or less were the next most common mechanism (n = 17). A fall from more than standing height accounted for 10 fractures.

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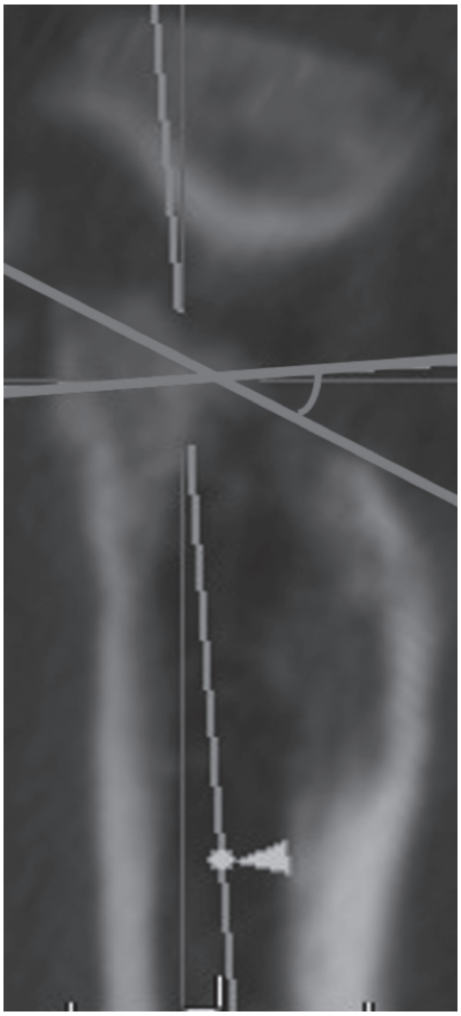

Fig. 5

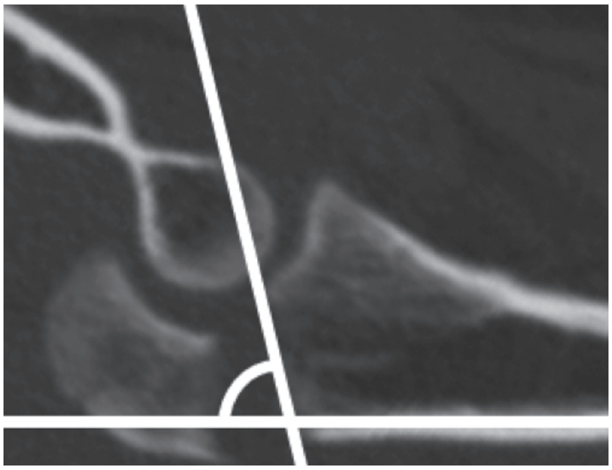

Fig. 6

All the fractures were classified according to the Mayo classification10. There were 5 type I fractures (non-comminuted), 40 type II (19 were comminuted), 3 type III (1 was comminuted), and 0 type I comminuted fractures.

The median tip radial edge was 1.96 ± 2.24 mm, the flat spot width was 12.64 ± 2.92 mm, and the tip radial ratio was 0.15 ± 0.7 mm. The radial inclination was 30.55 ± 9.16°, and lateral fracture line angle was 64.55 ± 16.36° (Table I). The intra-observer and inter-observer reliabilities, as measured by intra-class correlation coefficients, were 0.71-0.847 for different measures. The Cronbach's alpha values ranged from 0.702-0.847 and were for the different measures. The data related directly to the fracture line on the anteroposterior view were in the excellent range according to Shrout and Fleiss' benchmarks (poor, < 0.4 ; fair to good, 0.4-0.75 ; excellent, > 0.75) (*15*). The lowest values were still in the good range.

DISCUSSION

According to our findings, the tip of the olecranon fragment tends to be located on the radial side of the posterior and articular sides. In fact, fracture lines ran from the proximal ulnar side to the distal radial side in all cases on in the articular surface fracture line study in all cases, and in all but except 1 case, where the fracture lines were on in the posterior side fracture line study. Thus, our hypothesis was confirmed. In addition, the mean lateral fracture line angle was 0-90°, meaning that the tip of the fractured olecranon fragment tended to be located in the radial and posterior area of the proximal ulna. Orthopaedic surgeons as well as manufactures and researchers could benefit from this information.

Although the effects of compression on the cortical bone have been controversial, the use of axial

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Table I

Measures	Average	SD	Range	ICC	Cronbach α
tip-radial edge	1.96	2.24	0-6.13	0.782 (0.661-0.868)	0.793
flat spot width	12.64	2.92	7.57-19.74	0.730 (0.580-0.836)	0.816
tip radial ratio	0.15	0.17	0-0.55	0.759 (0.626-0.854)	0.849
radial inclination	30.55	9.16	9.27-43.68	0.847 (0.762-0.947)	0.798
lateral fracture line angle	64.55	16.36	36.86-108.14	0.708 (0.546-0.823)	0.702

SD : Standard Deviation.
ICC : Intraclass Correlation Coefficient.

compression for promoting union cancellous bone fractures – as originally described by Key and later popularized by Charnley – is now well accepted (*7*). The adequate compressive preload prevents displacement of the fracture fragments and results in absolute stability, as long as the compression produced is greater than any traction produced by function (*7*). The advantage of absolute stability is maintaining perfect reduction of the articular surface and allowing early functional rehabilitation (*7*). In addition, absolute stability has positive effects on the blood supply. Of course, there are some disadvantages. Osteosynthesis with relative stability should only be applied in multi-fragmentary fractures and must not be used for simple fracture configurations, because there is a high incidence of delayed union or non-union (*7*).

To generate an appropriate compression force across the fracture site, the ideal direction of the screw in the lag screw technique or of the Kirschner (K)-wires in the tension band wiring technique are perpendicular to the fracture plane (*14,19*). Therefore, the information obtained from this study about the fracture line is important. It may be enlightening to those who are involved in studies on new olecranon fracture treatments.

For surgeons, the present study's findings may could provide more information on how to set an appropriate direction and position for inserting K-wires in tension band wiring. To limit the potential for wire migration, several authors favour drilling the wires obliquely so that they pass through the anterior ulnar cortex (*6,10,12*). To create vertical compressive force across the fracture line, the wires should be inserted from the proximal-radial-posterior area to the distal-ulnar-anterior cortex. Using this direction of insertion, surgeons can could insert transcortical K-wires more easily, because the angle of insertion to the cortex becomes larger than when performing insertion in the anterior direction. Although there may be unexpected risks with performing these methods (e.g. penetrating the ulnar nerve), there is a possibility to improve the result of open reduction and internal fixation. Before the current study findings can be applied in a clinical setting, further discussion is required.

For implant manufacturers, our findings may suggest that setting the plate radially to support the fragment, at least at the proximal end of the olecranon, is reasonable for better osteosynthesis. However, no commercially available plate has been designed based on this concept. In contrast, some plates have dynamization holes for generating compression force in only the longitudinal direction, which may result in displacement of the reduced fracture site, owing to the generated shear compression force.

For researchers, the present study's findings may be important, because no recent study has shown an accurate simulated olecranon fracture with the shape of the olecranon fragment (*1,4,17*). Our findings will be helpful in designing an adequate olecranon fracture model.

The limitations of the present study include its retrospective nature, the small number of patients, and wide age range. The relationship among the fracture type, osteoporosis, and mechanism of injury may be elucidated in a study with more patients.

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CONCLUSIONS

Our findings confirming that the fracture line of the olecranon run from the proximal ulnar side to the distal radial side on the olecranon's posterior and articular surfaces could assist orthopaedic surgeons when determining the direction of the K-wire insertion during olecranon fracture fixation. Additionally, our findings may also help implant manufacturers develop accurate products and researchers to simulate olecranon fractures with proper models.

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