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Distal radius measurements and efficacy of fixed-angle locking volar plates

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Aim: For surgical treatment of unstable distal radius fractures, fixed-angled locking volar plate fixation is becoming popular nowadays because of some advantages over other surgical techniques. In this article, we discuss the fitting of fixed-angle locking volar plates to the distal radius in relation to the changes in the distal radial angles.

Materials and methods: First, we took conventional radiography images of 18 dried radii and later we measured the palmar subchondral angle, dorsal subchondral angle, mid-subchondral angle, and palmar cortical angle using lateral radiography.

Results: According to the measurements, the volar subchondral angles (alpha) ranged from 10.2° to 28.1°, the middle subchondral angles ranged from 55.9° to 93.2°, the dorsal subchondral angles ranged from 77° to 109.6°, and the volar cortical angles ranged from 134.5° to 158.4°.

Conclusion: Although fixed-angle locking volar plates are accepted as anatomical, our measurements showed that volar cortical angles and the subchondral angles are variable. Therefore, the term "anatomic distal radius volar plate" should be discussed.

Key words: Volar plate, distal radius, screw penetration

1. Introduction

The fracture of the distal radius accounts for one-sixth of all fractures treated in emergency care settings (1). After reduction and cast immobilization, good results can be achieved, but these fractures continue to be associated with significant morbidity (2). The surgical treatment of unstable distal radius fractures is generally preferred these days because of new surgical techniques and improved implant designs (3). There are many anatomic and morphometric studies about all human bones, as well as the distal radius (4–8).

Anatomic or near anatomic restoration, good stabilization, minimal traumatic surgery, pain control, and early progressive joint mobilization to prevent contracture constitute the basic principles of the operative management of fractures (9,10).

Among the present surgical techniques, treatment with fixed-angle locking volar plate fixation is becoming popular (11–14). The low rate of complications, such as tendon irritation and rupture, and tenosynovitis and scar formation as observed in the dorsal plate fixation technique may be the main reasons for the recent popularity of this technique (15). Because the flexor tendons are distant from bone and the pronator quadratus is interposed during surgery, the volar approach provides plenty of space between the structures that are prone to irritation (15,16). Furthermore, fixed-angle distal radius volar locking plates are systems that are angled to fit the palmar surface anatomically and have locking screws to fit the subchondral area at a fixed angle. These features facilitate the reduction, and fixation becomes more stable (17). This is crucial for an older population that encounters such fractures due to osteoporotic bone formation (2,9).

Despite the advantages mentioned in the preceding paragraph, complications arising because of these specifications have been shown in some studies. The disadvantages of this technique pertain to the difficulty in positioning the fixed-angle screw sockets on these plates during surgery, leading to the risk of sending the screws into the joint as well as not fitting the precontoured fixed-angle plates to the volar surface of the distal radius (3,18–20).

We observed the differences of volar cortical angles and subchondral angles using lateral radiography images of 18

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dry cadaver radii and discussed the possible complications and the efficacy of the distal radius due to the differences in these measures.

2. Materials and methods

We studied 18 dried adult cadaver radii. We excluded 5 dried cadaver radii having structural deformities, previous distal radial trauma, or any pathologic irregularity such as arthritis because these kinds of deformities could cause mismeasurement. Measurements were performed on 18 radii: 7 right and 11 left.

First, the lateral radiographic images of all the radii were obtained, followed by the measurement of the palmar subchondral angle, dorsal subchondral angle, mid-subchondral angle, and palmar cortical angle on these lateral radiographs. For measuring the palmar cortical angle in each case, a line was drawn along the palmar surface of the shaft of the distal radius. A second line was drawn parallel to the palmar cortex of the distal radius (palmar cortical line). The angle between these 2 lines was measured, which represented the palmar cortical angle (Figure 1).

For measuring the palmar subchondral angle, a tangent line was drawn from the most palmar point of the subchondral region. The angle between this line and the palmar cortical line was defined as the subchondral angle (alpha) (Figure 2).

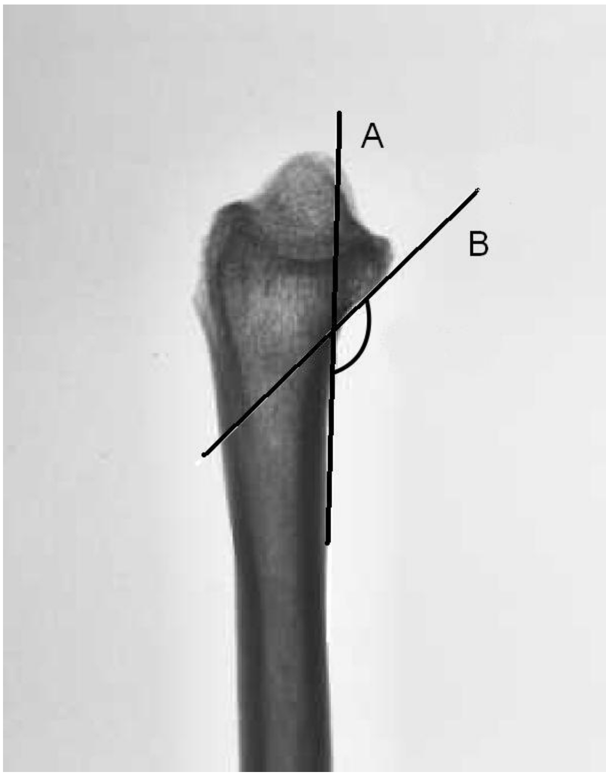

Figure 1. Volar cortical angle.

Figure 2. Alpha angle.

The angle between the tangent line drawn from the most dorsal point of the subchondral region and the palmar cortical line was defined as the dorsal subchondral angle (gamma) (Figure 3).

The midpoint between the most palmar and dorsal subchondral region was marked and a tangent line was drawn from the subchondral region including this point. The angle between this line and the palmar cortical line was defined as the mid-subchondral angle (beta) (Figure 4).

These measurements were performed with the help of Sienet Sky-Dicom-CD Viewer 2005 (SIENET Sky VA50B). Student's t-test was used as a statistical method (P = 0.05) for the evaluation of the variability of the volar angles of the distal radius.

3. Results

According to the measurements, the volar subchondral angles (alpha) ranged from 10.2° to 28.1°, with a mean value of 19.56° ± 5.22°, and the middle subchondral angles ranged from 55.9° to 93.2°, with a mean value of 67.34° ±

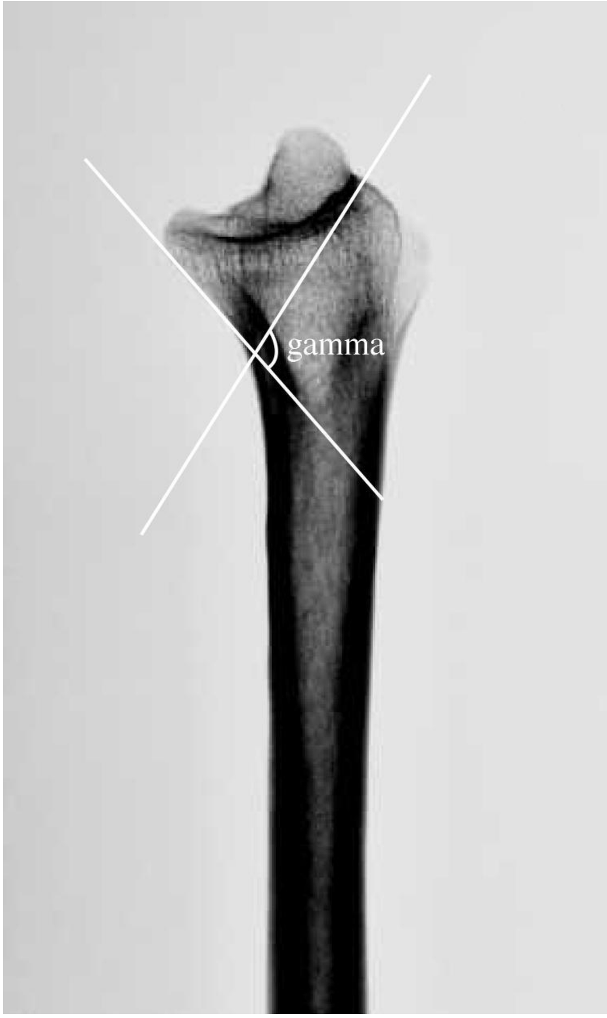

Figure 3. Gamma angle.

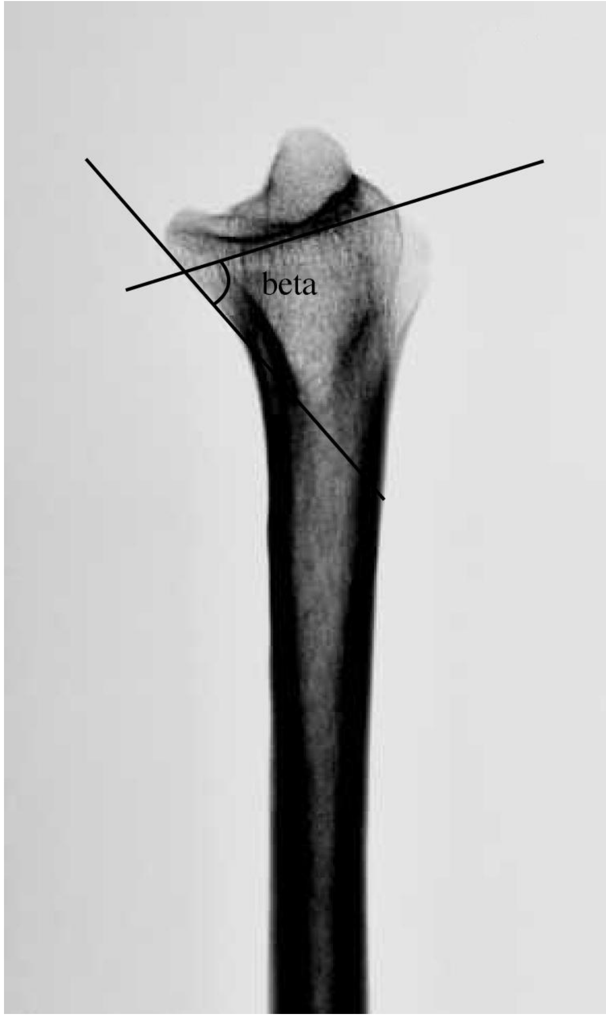

Figure 4. Beta angle.

8.96°. The dorsal subchondral angles ranged from 77° to 109.6°, with a mean value of 93.00° ± 9.88°, and the volar cortical angles ranged from 134.5° to 158.4°, with a mean value of 142.27° ± 6.76°. All results are summarized in the Table. Regarding the measurements, having the volar plate angle as a constant value, the variability of the distal radius volar angles is statistically significant.

4. Discussion

The use of volar buttress plating for volar displaced distal radius fractures has seldom been associated with flexor tendon problems (15,21).

When the quality of the pronator quadratus muscle is good, the volar-placed plates are almost covered with the pronator quadratus, except at the distal edge of the plate (17,18). Volar scars are better tolerated and less obvious, and the blood supply to the radius is less likely to be disrupted (17). The application of a strong fixed-angle implant, acting as an internal fixator, controls fracture collapse (9,24). Additionally, palmar plates can be supplemented as bone grafts or bone substitutes (14). Because of these advantages, palmar plate fixation has become increasingly popular among surgeons.

More than 30 designs of fixed-angle locking volar plates are now available (24). These volar plates are fixed-angle plates that have been shown to be biomechanically stronger than conventional volar and dorsal counterparts, and which allow early motion and may decrease the amount of early motion loss as seen in some other methods of fixation (20,25). The working portion of a buttress plate is the bar that is localized on the distal segment of the plate supporting the metaphyseal fracture fragments. Theoretically, distal radius locking plates are precontoured and do not have to be shaped. Basically they may act as an internal fixator (i.e. an implanted external fixator) (9). However, in our study, it is shown that the volar cortical angle is variable between individuals, and so prefixed-angle plates would not fit exactly. As seen in Figure 5,

Table. Measured angles (degrees) of the distal radii.

Radius	Alpha angle	Beta angle	Gamma angle	Volar cortical angle
1	20.3	66.8	105.9	136
2	27.4	93.2	1096	158.4
3	20.9	60.2	92.3	152.9
4	28.1	73.7	100.6	138.5
5	25.2	76.1	109	143.7
6	17.4	68.4	90.8	136.8
7	24.9	72.6	86.8	141.9
8	15.7	60.1	82.1	140.9
9	10.2	55.9	77	136.6
10	21.4	68.6	100.1	141.7
11	22.8	63.7	88.9	141.3
12	20.9	72.7	94.2	147.4
13	15.3	60.8	80.6	137.6
14	22.4	67.3	98.1	134.5
15	15.7	63	87.1	142
16	18	73	101.2	153.8
17	10.7	56	83.6	135.9
18	14.8	60.1	86.2	141
Mean	19.56	67.34	93	142.27
SD	5.22	8.96	9.88	6.76

the Acumed Acu-loc Standard plate does not fit to radius number 9, while the same plate is more suitable for radius number 13 (Figure 6).

These prefixed plates are said to facilitate the reduction of the fractured distal radius. However, this reduction will not be a true anatomic reduction because the fractured distal radius fragments fitting to the plate will accompany the volar angle of the plate itself, but not its original volar angle. Theoretically, volar plates are accepted as an implanted external fixator because the mobile fractured metaphysis will fit itself to the plate and the contact area will increase, making the internal fixator definition false, although it has low contact on a nonfractured metaphysis.

However, during surgery the plate can be bent for a true anatomical reduction if it is seen not to fit, as in Figure 6 for the Acumed Acu-loc Standard plate. In this case, the angle of screw holes will change, causing an intraarticular screw placement.

Figure 5. Acumed Acu-loc Standard plate does not fit to radius number 9.

Figure 6. Acumed Acu-loc Standard plate is more suitable for radius number 13.

Another inefficiency of the fixed-angle locking volar plates is seen in fractures including the volar lip. Volar concavity terminates distally at the volar lip of the distal radius, where flexor tendons glide in proximity to bone and are subject to abrasion by prominent hardware. This point is also referred to as the watershed line. Hardware placed at or beyond this point may lead to flexor tendon irritation and subsequent rupture (20,26). For the fixation of volar lip fractures, the volar plate should be placed distal to the watershed line. By this method, fixation can be achieved by a screw on the volar plate. In the study by Buzzell et al. (20), 7 volar plates were observed, and only the Synthes JA plate was found to be more distally placed. The Synthes JA plate had distal pegs with 5° of volar angle proximally, making the volar angle 85°, which is higher than our measurements**.** That is why volar lip fractures fixation can be achieved with a screw beside the distal radius volar plate for a distal radius fracture (Figure 7).

Biomechanical studies of fixed-angle locking plates have shown improved maintenance of reduction when the screws and plate are in maximum proximity to the subchondral bone (3). The placement of screws 4 mm proximal to the subchondral bone leads to radial shortening because the subchondral bone collapses due to inadequate support of the load on the distal fragments (2,3). A narrow margin exists between placing the supports too proximally and too distally. Because of the volar angle and volar height variabilities, as shown in our study, precontoured fixed-angle plates cannot be placed in their anatomic positions, they will slide to the joint, and the screws may not be placed near enough to the subchondral bone to achieve stability**.** In addition to this, although the mid-subchondral and dorsal subchondral angles are variable, the sockets for the screws are at a fixed angle, causing the targets of these screws to be fairly variable.

Our measurements show that volar cortical angles and subchondral angles are variable. Problems during surgery may be curbed by taking this variability into consideration.

Figure 7. A volar lip fracture fixed with 2.4-mm screw and titanium 2.4 T-plate.

During surgery, there should be a plate bender in the surgical set to help bend the plate if it does not fit after the reduction is achieved. This is required to avoid the risk of screw place shifting. For a safer fixation, in terms of placing screws nearer to the subchondral bone and reducing the risk of placing them into the joint space instead of fixed-angle screw slots, combihole or multidirectionally self-taping plates should be used, which are achieved by different degrees of hardness of plate and screws. As a final suggestion, by measuring the contralateral distal radius volar angles before the surgery, the plate can be adjusted to the true volar angle, resulting in a true anatomic reduction with no time wasted during the surgery.

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