

Three-dimensional Analysis of Proper Positions of Volar Locking Plate for Distal Radius Fractures

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INTRODUCTION: Volar locking plate (VLP) is commonly used for the osteosynthesis of distal radius fractures. When applying the VLP, the plate and screws must be placed accurately and safely for the subchondral support. When using fixed-angle plates, this can be difficult to achieve due to variations in fracture fragments size and location. Variable angle screws allow plate positioning to match the fracture types in both the proximal-to-distal and radial-to-ulnar planes. This position adaptation can be achieved while minimizing the risk of screw penetration of either the distal radio-ulnar or radio-carpal joints by keeping the screws away from the joint. To avoid screw penetration into the joint when using the variable angle (polyaxial) VLP for the osteosynthesis of distal radius fractures, it is important to note that the optimal plate position depends on the insertion angles of the distal screws. In this study, we analyzed the optimal plate positions at different screw angles of the polyaxial VLP in three-dimensional (3D) radius models. The purpose of the present study was twofold; first, to evaluate differences of the optimal plate positions with different screw insertion angles of polyaxial VLP, second, to evaluate the relationship between the optimal position of the polyaxial VLP and the transverse diameter of the distal radius.

METHODS: The study protocol was approved by the Institutional Review Board. This was a retrospective case control study (level of evidence III). We evaluated the image data of 30 patients acquired at one university hospital (12 females, 18 males, mean age 56.3 years, age range 18-81). From the image database, we evaluated thirty plain X-rays and CT scans of healthy wrists taken for comparison with the affected side wrist. The radiographic database was accessed to identify cases with X-rays and CT scans of normal wrists. Anterior-posterior X-rays were taken from the dorsal side with the cassette placed on the palmar surface of the wrist in the neutral position of the wrist joint. CT images were taken with a tube setting with section thickness of 1-1.5 mm (Sensation Cardiac, Siemens). CT images were taken from the metacarpal bone level to approximately 13 cm proximal to the radius joint surface in the forearm neutral position. The transverse diameter of radius (W) was measured at the ulnar margin level of the distal radius articular surface drawn orthogonally to the radial bone axis on X-ray images. For the assessment of plate positions, 3D models of the radius were reconstructed from CT data. BoneSimulator (Ortho3, Osaka, Japan) was used to define the coordinate system based on the 3D model of the distal radius (Fig.1). The long axis of the radius was automatically defined as follows. The central curve of the radius shaft from the proximal to the distal end was measured by analyzing cross-sections at different levels. It then calculated the central point at each level from surface data of the radial diaphysis. The long axis of the radius was subsequently defined as a straight line based on each center point. For the 3D data of volar locking plate, we used a 3D model of standard size EVOS wrist plate system (Smith & Nephew plc, Watford, UK), as a representative example of polyaxial volar locking plate. The most distal plate positions at three different distal screw insertion angles, i.e., 0 degrees (group N), 15 degrees of the distal swing (group D), and 15 degrees of the proximal swing (group P) were evaluated. 3D data of the plate were placed on the volar surface of the radius along the long axis and moved distally along the long axis. The most distal position at which the distal screw did not penetrate the articular surface was identified. The linear distance (distance on the long axis of the radius, Da) between the volar articular edge and the distal end of the plate was measured and compared among different screw insertion angles (Fig.2). One-way analysis of variance was used to compare the differences in plate positions with different screw angles. The relationship between Da and W was evaluated by Pearson's correlation analysis. P values of less than 0.05 were considered to be significant.

RESULTS: The average transverse diameter (W) was 29.4 ± 2.3 mm. Linear distances (distance on the bone axis, Da) were 2.3 ± 0.8 mm, 4.9 ± 1.0 mm, and 0.4 ± 0.7 mm in group N, group D, and group P, respectively. Group D positions were 2.7 ± 0.6 mm proximal to the group N. Group P positions were 1.9 ± 0.6 mm distal to the group N. Significant differences were observed among the three groups ($P < 0.05$). The correlation coefficients between W and Da were 0.474, 0.653, and 0.435 for group N, group D, and group P, respectively. There were significant correlations between Da and W in all three groups. Regression equations were $Da = 0.17W - 2.6$, $Da = 0.27W - 3.1$, and $Da = 0.14W - 3.7$ in group N, group D, and group P, respectively (Fig.3).

DISCUSSION: In the present study, we analyzed the most distal position of the volar locking plate at different screw insertion angles in the polyaxial VLP with 3D radius models. Computerized anatomical assessment is useful because it is non-invasive, non-destructive and reproducible, allowing detailed anatomical examination. Recently, digital preoperative planning was suggested to optimize not only implant selection and placement, but also screw lengths. The results showed that the most distal placement positions to avoid intra-articular screw penetration were 2.7 mm proximal at 15 degrees of the distal swing and 1.9 mm distal at 15 degrees of the proximal swing compared to the neutral screw angle. This difference should be considered when using the poly-axial volar locking plate. In addition, the optimal plate position was found to be proximal to the larger radius transverse diameter. The formula identified from this study may be useful in knowing the optimal plate position prior to surgery.

SIGNIFICANCE/CLINICAL RELEVANCE: The differences of the optimal plate positions with different screw insertion angles of volar locking plate were clarified. The results will be useful as a reference for the positioning of the plate prior to the surgery.

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IMAGES AND TABLES:

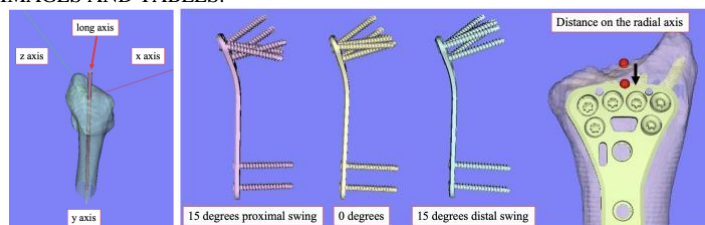


Fig.1

Fig.2

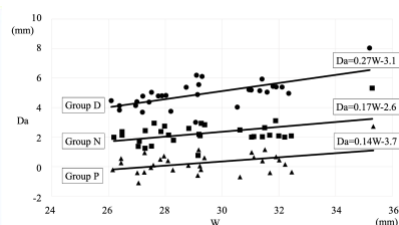


Fig.3