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Assessment of glenoid inclination on routine clinical radiographs and computed tomography examinations of the shoulder

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Background: Accurate assessment of glenoid inclination is of interest for a variety of conditions and procedures. The purpose of this study was to develop an accurate and reproducible measurement for glenoid inclination on standardized anterior-posterior (AP) radiographs and on computed tomography (CT) images.

Materials and methods: Three consistently identifiable angles were defined: Angle α by line *AB* connecting the superior and inferior glenoid tubercle (glenoid fossa) and the line identifying the scapular spine; angle β by line *AB* and the floor of the supraspinatus fossa; angle γ by line *AB* and the lateral margin of the scapula. Experimental study: these 3 angles were measured in function of the scapular position to test their resistance to rotation. Conventional AP radiographs and CT scans were acquired in extension/flexion and internal/external rotation in a range up to $\pm 40^\circ$. Clinical study: the inter-rater reliability of all angles was assessed on AP radiographs and CT scans of 60 patients (30 with proximal humeral fractures, 30 with osteoarthritis) by 2 independent observers.

Results: The experimental study showed that angle α and β have a resistance to rotation of up to $\pm 20^\circ$. The deviation from neutral position was not more than $\pm 10^\circ$. The results for the inter-rater reliability analyzed by Bland-Altman plots for the angle β fracture group were (mean $\pm$ standard deviation) -0.1 ± 4.2 for radiographs and -0.3 ± 3.3 for CT scans; and for the osteoarthritis group were -1.2 ± 3.8 for radiographs and -3.0 ± 3.6 for CT scans.

Conclusion: Angle β is the most reproducible measurement for glenoid inclination on conventional AP radiographs, providing a resistance to positional variability of the scapula and a good inter-rater reliability.

Level of evidence: Basic Science Study, Anatomic Study, Imaging Study.

Keywords: Glenohumeral joint; measurement glenoid inclination; conventional radiographs; CT scans; rotator cuff tears; superior humeral head migration; shoulder arthroplasty

The orientation of the glenoid is important for the biomechanics of the glenohumeral joint. The knowledge of the exact orientation of the glenoid is essential for the understanding of various shoulder conditions. An abnormal

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inclination of the glenoid may be associated with rotator cuff tears[9-11] and superior humeral head migration.[5,19] Some studies analyze the influence of the glenoid component inclination in shoulder arthroplasty.[1,7,8,11,15,17,18] A valid and reproducible technique for measuring the inclination of the glenoid using routine clinical imaging is, however, not available to our knowledge. Anatomic studies have measured the inclination of the glenoid directly on the scapular bone[4] or on radiographs.[13] These studies provide exact information on the orientation of the glenoid. These methods for the assessment of the inclination of the glenoid are not routinely applicable in clinical practice because the anatomic references are usually not available on routine imaging.

The purpose of this study was to develop a robust and reproducible measurement method for glenoid inclination that can be used on routine images such as standard conventional anterior-posterior (AP) radiographs and CT examinations of the shoulder.

Material and methods

Definition of anatomic landmarks and angles

To assess which parts of the scapula and which anatomic landmarks are consistently available for analysis, 30 AP radiographs and 30 CT scans of shoulders were reviewed. The following landmarks were consistently detectable on all AP radiographs and CT scans of the shoulder and were therefore considered suitable for angle definition: The articular surface of the glenoid fossa, the scapular spine, the floor of the supraspinatus fossa, and lateral margin of the scapula. On conventional radiographs, the scapula is visible for a mean ± standard deviation (SD) distance m_1 of 73 ± 20.3 mm (range, 39.4-104.7 mm) medial to the glenoid (Fig 1). On CT scans, the scapula is visible for a mean distance m_2 of 63 ± 22.3 mm (range, 31.9-145.1 mm) medial to the glenoid (Fig 2, *A*).

Figures 1 and 2 show the definition of the angles for glenoid inclination measurement on conventional radiographs and on CT images. The glenoid fossa line is the baseline for all angles tested. On conventional radiographs (Fig. 1), the glenoid fossa line (*AB*) is defined as a line connecting the uppermost point (*A*) and the lowermost point (*B*) of the glenoid. On CT images (Fig. 2, *A*), the glenoid fossa line is defined on the coronal oblique image through the center of the glenoid connecting the uppermost point (*A*) and the lowermost point (*B*) of the glenoid.

Angle α: Angle between the spine of the scapula (*a*) and glenoid fossa line (*AB*). On conventional radiographs, line *a* is placed in the upper cortical margin of the spine. Only the part of the spine medial to the glenoid is used; lateral to the glenoid, the spine is usually curved (Fig. 1). On CT images, the coronal image displaying the largest portion of the spine is selected. Corresponding to conventional radiographs, line *a* is defined by a tangent on the upper cortical margin of the spine, medial to the glenoid (Fig. 2, *B*).

Angle β: Angle between the floor of the supraspinatus fossa (*b*) and the glenoid fossa (*AB*). On conventional radiographs the floor of the supraspinatus fossa is visible as a sclerotic line (Fig. 1, line *b*). On CT images, the coronal section to the deepest point (Fig. 2, *A*) of the supraspinatus fossa is used. Line *b* is placed along the cortical margin of the floor of the supraspinatus fossa.

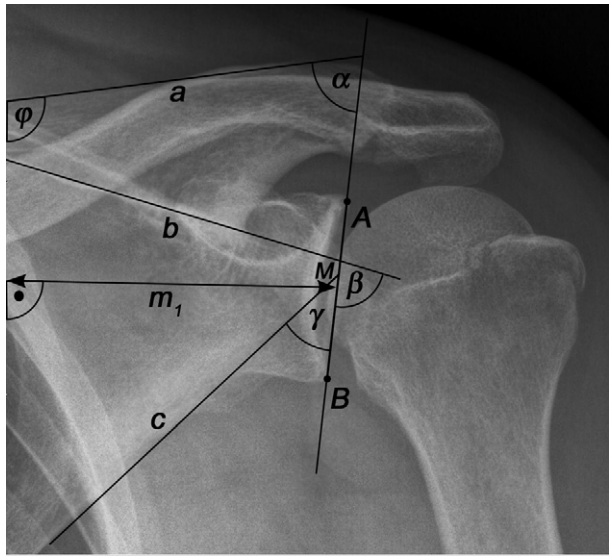

Figure 1 Definition of angles on conventional radiographs. The glenoid fossa line (*AB*) is defined as a line connecting the uppermost point (*A*) and the lowermost point (*B*) of the glenoid. Angle α is the angle between the spine of the scapula (*a*) and glenoid fossa line (*AB*). Angle β is the angle between the floor of the supraspinatus fossa (*b*) and the glenoid fossa line (*AB*). Angle γ is the angle between the lateral margin of the scapula (*c*) and the glenoid fossa line (*AB*). The distance from the medial border of the radiograph and the center of the glenoid fossa line (*AB*) is m_1. The angle between the scapular spine (*a*) and the medial border of the radiograph is φ.

Angle γ: Angle between the lateral margin of the scapula (*c*) and the glenoid fossa (*AB*). On conventional radiographs line *c* is placed on the cortical border of the lateral margin of the scapula medial to the neck of the glenoid (Fig. 1). On CT images, the coronal sections optimally displaying the lateral margin of the scapula (Fig. 2, *A*) are used. Corresponding to the conventional radiographs, line *c* is placed on the cortical border of the lateral margin of the scapula medial to the neck of the glenoid.

Experimental study

The experimental study investigated the behavior of the angles in the function of the position of the scapula. Two dry left scapulae from adult deceased donors were used to test the influence of different positioning on the 3 glenoid inclination angles. A device for fixation of a scapula that allows incremental rotation and flexion and extension of the scapula was built (Fig. 3). With this device, the dry scapula could be rotated in steps of 10° in extension/flexion, in internal/external rotation, and in combination. Extension is defined as a rotation in the direction of the scapular spine. Flexion refers to a rotation in the direction of the coracoid process. External rotation or extension is indicated with positive degrees, and internal rotation or flexion is marked with negative degrees.