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Comparison of glenoid inclination angle using different clinical imaging modalities

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Background: The β-angle, formed by the intersection of a line on the floor of the supraspinatus fossa and glenoid fossa line, has been described as a reliable measurement tool in the clinical setting to analyze glenoid inclination on the anteroposterior (AP) view of the shoulder. The purpose of this study was to compare the accuracy of the β-angle measurement using different imaging modalities with a validated 3-dimensional (3D) software tool.

Materials and methods: The β-angle was measured on AP radiographs, unformatted 2-dimensional (2D) computed tomography (CT) scan, and reformatted 2D CT scan in the scapular plane for 51 shoulders of 49 patients undergoing primary total shoulder arthroplasty. Comparison to the glenoid inclination angle calculated by the 3D software was performed.

Results: The β-angle measured on reformatted CT scan was found to be the most accurate measurement method, with a mean difference of 1° (standard deviation [SD], 0.5°) with respect to 3D measurement. On AP radiographs, the β-angle was not as accurate, with a mean difference of 3° (SD, 0.7°; $P < .006$). The β-angle on unformatted 2D CT scan was not a reliable method to measure glenoid inclination, with a mean difference of 10° (SD, 0.9°; $P < .0001$).

Conclusion: The β-angle measured with 2D CT scan formatted in the scapular plane was the most accurate method for measuring glenoid inclination. The β-angle on the AP radiograph is less accurate and reliable. Measurement of the β-angle on an unformatted 2D CT scan is not an acceptable method to determine glenoid inclination.

Level of evidence: Level III, Diagnostic Study.

Keywords: Glenoid inclination; β-angle; CT scan; measurement method; 3D software

Glenoid inclination is defined by the angle of the glenoid in the plane of the scapula and has recently been identified as a potential contributor to disorders of the glenohumeral joint.[2,5,8,9,11,14,15,18,19] In the native shoulder, increased glenoid inclination has been implicated as a risk factor for rotator cuff tears[8,14] and superior migration of the humeral head.[19] In shoulder arthroplasty, proper implant positioning in the vertical plane of the glenoid is crucial to maximize outcomes and long-term implant survivability.[4,6,11,15,16]

To date, a variety of methodologies have been used to measure the glenoid inclination through imaging.[2,10-12] One method, termed the β-angle, has been published by Maurer et al,[13] with good accuracy and interobserver reliability on both radiographs and reformatted 2-dimensional (2D) computed tomography (CT) scan. Although it is not yet

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widely available, an innovative 3-dimensional (3D) software program has allowed a more thorough and accurate depiction of the inclination plane of the glenoid, with measurements having a mean inclination error of only 1.4° compared with actual anatomy[18]; however, the use of 3D reconstruction from 2D CT scans to measure glenoid inclination has yet to be validated. Currently, radiographs and 2D CT scans are most often used in the clinical setting secondary to their widespread availability.

Only a few published studies investigate the accuracy of glenoid inclination measurement and its impact on disorders of the shoulder. The purpose of this study was to determine the accuracy of the measured β-angle using multiple different imaging modalities taken directly from the everyday clinical setting and to compare these findings with the glenoid inclination measurement obtained by the validated 3D software.

Materials and methods

This retrospective analysis included 49 individuals (28 women, 21 men) for a total of 51 shoulders with an average age of 72 years (range, 64-88 years). Study participants were candidates for primary total shoulder arthroplasty taken randomly from within the clinical practice of the senior surgeon. All participants had an anteroposterior (AP) radiograph in neutral rotation of the shoulder as well as a CT scan. These images were obtained from the patient's existing clinical chart to replicate a typical clinical setting. Two shoulder surgeons (M.D., B.W.) independently measured the β-angle using 2 different techniques for each patient.

The β-angle, as described by Maurer et al,[13] was measured on an AP radiograph with the arm in neutral rotation (Fig. 1). It is defined as the measurement of the angle between the floor of the supraspinatus fossa marked by a sclerotic line and the glenoid fossa line.[13] Glenoid inclination thus is a 90° β-angle, with positive results indicating superior glenoid inclination and negative results indicating inferior glenoid inclination.

Measurements on unformatted 2D CT scans were performed in the coronal plane using the OsiriX software (Pixmeo Sarl, Bernex, Switzerland). The β-angle was measured on the 2D coronal section to the deepest point of the supraspinatus fossa (Fig. 2).

With a 3D software program (Imascap, Brest, France), an automatic segmentation process was performed, creating a 3D model of the scapula and proximal humerus.[18] After segmentation and reformatting, the software program determines the planes of the scapula and the glenoid fossa through best plane fitting to the 3D point cloud of the scapula. After reformatting of the plane of the scapula, a 2D coronal series of images is provided by the software. As the third measurement, the β-angle was evaluated on this reformatted 2D CT scan of the shoulder within the 3D software.

The final glenoid inclination angle obtained was the 3D measurement that was provided by the software program. This measurement is formed by the angle between the transverse axis of the scapula and the glenoid fossa plane and was used as the reference in the evaluation of the accuracy of the other measurement techniques (Fig. 3).

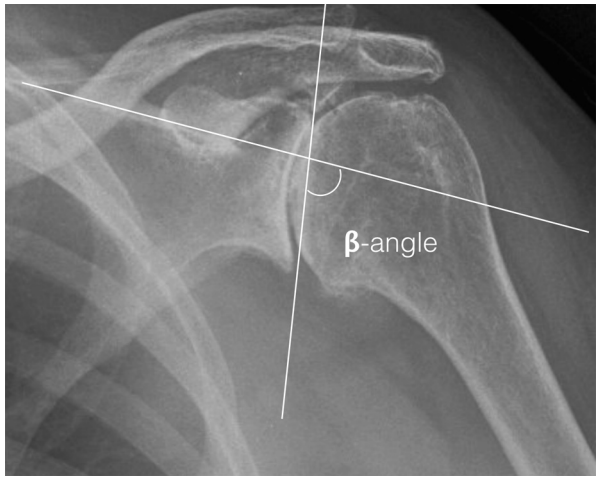

Figure 1 The β-angle, defined as the angle between the floor of the supraspinatus fossa marked by a sclerotic line and the glenoid fossa line.[13]

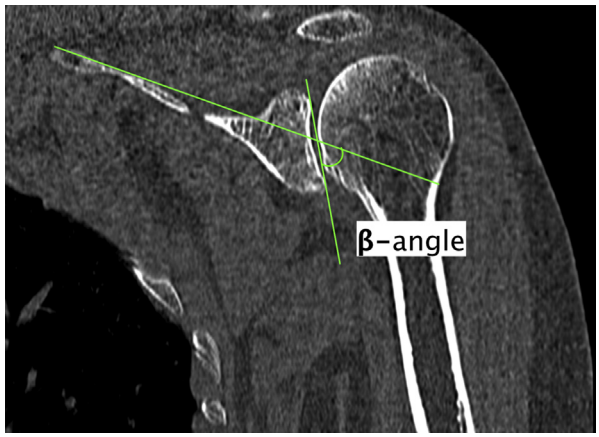

Figure 2 The β-angle as measured on unformatted CT scan of the shoulder.

Statistics

The intraclass correlation coefficient (ICC) was calculated to determine the reliability of β-angle measurements on both the AP radiograph and unformatted 2D CT scan. Analysis of variance was used to compare the accuracy of different methods of measuring glenoid inclination. The level of significance was set at $P = .05$.

Results

The β-angle measured on reformatted 2D CT scan was found to be the most accurate measurement method, with a mean difference of 1° (standard deviation [SD], 0.5°) from the 3D glenoid inclination as measured by the 3D software (Fig. 4). Measurement of the β-angle on the AP radiograph was not as accurate, with a mean difference of 3° (SD, 0.8°; $P < .0059$). The β-angle measured on unformatted 2D CT was not an accurate reflection of the glenoid inclination,