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ORIGINAL ARTICLE

Can the contralateral scapula be used as a reliable template to reconstruct the eroded scapula during shoulder arthroplasty?

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Hypothesis: The contralateral scapula can be used as a reliable template to determine scapular offset, glenoid inclination, and version of the native scapula in view of reconstructing pathologic scapulae.
Methods: Three-dimensional measurements of scapular offset, inclination, and version were performed using data from a set of 50 bilateral computed tomography scans of full scapulae to determine direct side-to-side differences.
Results: The scapula pairs had a mean bilateral difference of 2 mm in offset, 2° in inclination, and 2° in version. Ninety percent of the scapula pairs showed an offset difference smaller than 3 mm. In 96% and 94% of the scapula pairs, the inclination difference and version difference, respectively, were smaller than 5°. The maximum bilateral difference for offset, inclination, and version was 6 mm, 6°, and 8°, respectively.
Discussion and Conclusion: The anatomic parameters of scapular offset, glenoid inclination, and version are quite symmetrical and fall into the currently technically feasible accuracy of shoulder arthroplasty implantation. The healthy scapula can be used as a template to guide the reconstruction of the glenoid during shoulder arthroplasty planning in the case of unilateral advanced arthropathy.
Level of evidence: Anatomy Study; Imaging

Keywords: Scapular morphology; glenoid erosion; version; inclination; offset; between-side difference; symmetry

Glenohumeral arthropathy can be characterized by scapular bone loss leading to a distorted scapular morphology.[25,32] With the help of modern planning and guiding techniques, surgeons can reconstruct scapular morphologic parameters such as version and inclination with an accuracy of a few degrees during shoulder arthroplasty.[8,26] Optimal reconstruction of the native joint anatomy in terms of glenoid version and inclination in the case of total shoulder arthroplasty (TSA) has

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been reported to affect glenoid component survival and functional outcome.[9,13,15,19,24,33] However, as scapular morphology parameters have a wide range of normal values,[5] the native scapular anatomy should be known when planning and performing a TSA, which can be challenging, given the presence of substantial scapular bone loss. To overcome this, it has been suggested to use the contralateral scapula as a more "patient-specific" template.[2,18]

In this light, previous research has tried to investigate the intraindividual correlation of anatomic parameters of glenoid morphology such as version and inclination. Most of this research only reported means and no direct side-to-side differences, therefore limiting its potential for further clinical use. Furthermore, the reported values were determined with the help of standard radiographic or single-slice, 2-dimensional (2D) computed tomography (CT) scan measurements.[2,6,18,21,31,34] These techniques have poor reliability as a result of variations in the gantry angle at the time of CT or plain-film acquisition.[3,7,17,22,23,27,29] In contrast, 2D measurements in which the 2D images are first corrected to the plane of the scapula by 3-dimensional (3D) reconstruction have shown lower variability.[4,7,16,20] Nevertheless, with this method, we still have to choose a certain 2D slice for measurements. This inevitably results in intraobserver and interobserver variability and high labor intensity, further limiting its clinical application potential.[1,4,10] More automated 3D measurements can overcome these problems.[12]

The goal of this study was to determine, with the help of direct 3D measurements, whether the contralateral scapula can be used as a reliable template to determine scapular offset, glenoid inclination, and version of the native scapula in view of reconstructing pathologic scapulae. Our hypothesis was that the anatomic parameters of glenoid inclination and version and scapular offset would be symmetrical.

Materials and methods

Data

This is a prospective diagnostic study. We obtained 66 bilateral CT scans of the entire scapula from patients without glenohumeral arthropathy presenting to our outpatient clinic. The CT scan (BrightSpeed; GE Healthcare, Diegem, Belgium) parameters were as follows: 512 × 512 matrix, 50-cm field of view, and slice spacing of 1.25 mm. The CT scan images were reviewed by the first author for any signs of bone lesions (osteophytes, joint space narrowing, subchondral sclerosis, or cysts). If any bony lesion was present, the CT scan data were excluded. We finally included data from 50 bilateral CT scans of full scapulae.

Measurements

Inclination, version, and scapular offset were computed for all scapulae. To do so, the anonymized Digital Imaging and Communications in Medicine images were segmented using medical imaging software (Mimics; Materialise, Leuven, Belgium) and converted to 3D scapula models. Next, the 3D scapula models were uploaded in a custom-made software application, developed in Python 3.5 (Python Software Foundation, Wilmington, DE, USA), for easily indicating the required landmarks. First, the trigonum spinae and angulus inferior were indicated in accordance with International Society of Biomechanics recommendations.[35] Next, the glenoid rim was identified by indicating a minimum of 10 points along the rim. To compute the glenoid plane and center point, a basis spline—a smooth curve—was fitted through the indicated rim points and automatically resampled to equally distributed points with a uniform distance of ±3 mm between them (Fig. 1). The glenoid center point was defined as the mean point of the resampled rim points, whereas the glenoid plane was defined as the least-square best-fit plane. Furthermore, the scapular plane was formed by the glenoid center point, trigonum spinae, and angulus inferior.[20] The plane through the glenoid center point and trigonum spinae and going perpendicular to the scapular plane represented the axial plane. The axis between the glenoid center point and trigonum spinae point is called the "centerline." To assess inclination and version, the glenoid plane normal was projected to the scapular plane and axial plane. Then, the angle between the projected glenoid plane normal and the centerline was measured in both planes to obtain glenoid inclination and version, respectively (Figs. 2 and 3). Last, scapular offset was computed as the distance between the glenoid center point and trigonum spinae. To assess repeatability and reliability, all landmark indications and corresponding measurements were repeated twice by 2 individual surgeons (1 orthopedic fellow and 1 senior resident). This resulted in 4 sets of inclination, version, and offset values for each scapula.

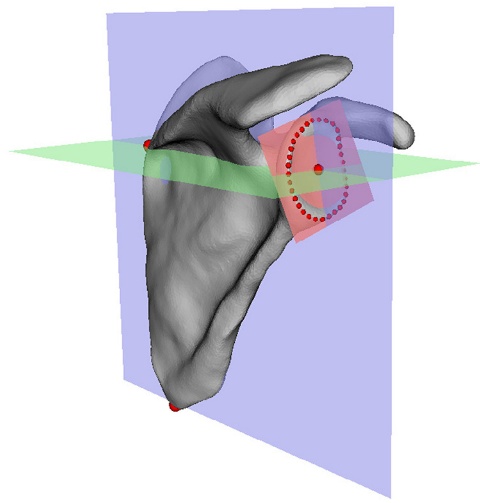

Figure 1 Three-dimensional view indicating the different planes and anatomic landmarks. The scapular plane (*blue*) is the plane through the trigonum spinae (*upper left red dot*), angulus inferior (*lower red dot*), and glenoid center point (*upper right red dot*). The axial plane (*green*) is the plane parallel to the trigonum spinae–glenoid center point axis and perpendicular to the scapular plane. The glenoid center point is the mean of uniformly distributed points along the rim, whereas the glenoid plane (*red*) is defined as the best-fitting plane through these rim points. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)