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2D measurements vs. 3D measurements for total shoulder replacement

Gilles Walch, MD

Jean Chaoui, PhD

White paper

Error sources in 2D glenoid measurements	Why are 3D glenoid measurements more accurate?
Patient positioning in the CT machine introduces errors in the three anatomical planes (coronal, sagittal and axial).	Measurements in 3D are completely independent of patient positioning. In others words, a patient positioned in three different orientations will all produce the same glenoid version and inclination measurements.
Version and inclination 2D measurements change through slices progressing further from the midline superior-to-inferior and anterior-to-posterior.	Version and inclination 3D measurements are calculated using all of the points on the face of glenoid to form a best-fit sphere.
The 2D humeral head subluxation is based on: 1) Both the Friedman's line which is supposed to represent the scapular plane 2) The assessment of the humeral head diameter only	3D humeral head subluxation is based on both the scapular plane generated from the entire scapula, and the whole humeral head volume.

There are several advantages of 3D measurements, such as those calculated by Blueprint (figure 1), to 2D measurements when performing a pre-operative planning for total shoulder arthroplasty (figure 2). The aim of existing 3D methods is to provide more accurate and reliable data of native shoulder anatomy, such as glenoid version/inclination, glenoid wear pattern and humeral head subluxation.

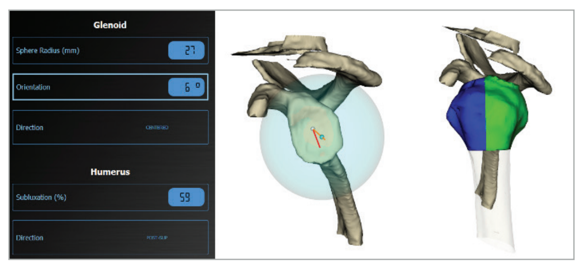

Figure 1. "Advanced measures" screen, available in Blueprint, providing specific measurements of the native shoulder anatomy.

Currently, numerous surgeons are using either 2D radiographs or 2D-CT slices as gold standards for planning the surgeries. Hoenecke et al.[1] have proved that "standard 2D-CT slices were not as accurate as 3D reconstructions for measurements of glenoid version and for locating the direction of maximum wear". The authors support the need for full 3D-CT reconstruction for preoperative planning in complex cases. Budge et al.[2] reported that 2D measures underestimate glenoid retroversion compared to 3D measures. Axial 2D images were 5° to 15° different than the 3D measures in 47% of the measurements.

In addition, Terrier et al.[3] showed that the mean version measured in 2D to obtain the classification of Walch was 9°. **It was significantly lower in 2D than in 3D for A1 and B2. The version was under-evaluated in 2D by more than 5° and 10° in 34% and 13% of cases respectively.**

Figure 2. Main window of Blueprint for selecting the suitable position of the glenoid implant in accordance to the version, the inclination, the reaming depth and the seating.

The glenoid inclination is also an important parameter highlighted by 3D method emergence. Daggett et al.[4] concluded that the ß-angle (defined by Maurer et al.[5]) measured with 2D CT scan formatted in the scapular plane using Blueprint, was the most accurate method for measuring glenoid inclination. This technique was compared to two others methods using 2D radiographs and unformatted 2D CT scan. The authors confirm that "the 3D software provides the closest depiction of scapular anatomy."

The reliability and reproducibility of Blueprint has also been demonstrated by Moineau et al.[6] when calculating several parameters of arthritic glenoid cavities. The authors declared that "these 3D measurements are advantageous because they are free of problems related to patient positioning in the CT scanner and to the choice of slices, which limits the accuracy of measurements made on slices from 2D CT scans."

A suitable pre-operative planning also involves the humeral component, which is strongly related to the glenoid and rotator cuff wears. Terrier et al.[7] have shown that 3D measurement of scapulohumeral subluxation should be preferred to the usual 2D measurement of glenohumeral subluxation. Jacxsens et al.[8] compared humeral subluxation on 2D and 3D imaging, and determined that **2D measurements underestimated posterior subluxation compared to 3D measurements.**

These studies illustrate that 3D measurements allow surgeons to get a more accurate representation of the real patient shoulder.

References

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