Sequential Three-dimensional Computed Tomography Analysis Of Implant Position Following Total Shoulder Arthroplasty

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Introduction: Glenoid component loosening is the most common complication following total shoulder arthroplasty (TSA). However, routine methods of postoperative imaging to assess for component position and loosening following TSA, including plain radiographs and two-dimensional (2-D) computed tomography (CT), have shown limitations in terms of precision and accuracy of measurements and may not be able to detect more subtle changes in component position over time. As a result, the predictors of loosening and their impact on clinical outcomes are still not well defined. Therefore, the purpose of this study was to evaluate glenoid component position over time using three dimensional computed tomography (3-D CT) analysis with minimum 2 year follow-up.

Methods: At mean follow-up of 32 months (range, 27-37), 19 patients who underwent TSA with a polyethylene anchor peg glenoid component were evaluated with routine plain radiographs and clinical outcome measures (Penn Shoulder score, shoulder range-of-motion). In addition, all patients underwent sequential CT scanning of the shoulder; a preoperative study, an immediate postoperative study within 2 weeks of surgery (CT1), and a postoperative study performed at latest follow-up (CT2). An anatomic coordinate system was defined by three scapular landmarks (glenoid center, trigonum, and angulus inferior), with the sequential 3-D CT scans reconstructed into volumes that were registered to the preoperative scapular volume. The locations of the glenoid component and humeral head were defined by placement of matching digital templates of both structures across sequential 3-D CT scans using custom-designed image analysis software. Glenoid component position (mm) was measured in the superior-inferior (SI), anterior-posterior (AP) and medial-lateral (ML) dimensions. Glenoid component orientation (degrees) was measured as version, inclination, and sagittal plane roll. Humeral head alignment to the glenoid component was evaluated by two measurements. The perpendicular distance from the center of the humeral head to a line normal to the glenoid component surface was defined as humeral-glenoid alignment (HGA), while the perpendicular distance from the center of the humeral head to a line normal to the plane of the scapula was defined as humeral-scapular alignment (HSA). Both HGA and HSA were measured (mm) in the AP and SI planes, with values then normalized as a percentage of the humeral head diameter. Backside support of the glenoid component and presence of peg radiolucencies were also assessed on postoperative CT scans and compared to findings on plain radiographs. Glenoid component loosening was defined as component shift of ≥5 degrees in any plane and/or evidence of complete peg radiolucencies in all pegs on CT2.
**Results:** At latest follow-up, 7 patients (37%) showed evidence of glenoid component loosening on CT2; 6 by glenoid component shift and 1 by complete peg radiolucencies in all pegs (Figure 1). Of those with shift, 5 patients had increased component inclination, 3 had increased component retroversion, and 2 patients had both findings. A higher percentage of patients with loosening had an increase of HSA-SI from CT1 to CT2 (86% vs. 33%, p=0.03) and osteolysis of the central anchor peg on CT2 (86% vs. 0%, p<0.01) compared to patients without loosening. Patients with loosening on CT showed no evidence of glenoid component shift on plain radiographs, and only 4/7 showed central peg osteolysis on x-rays. Only 1 patient with loosening showed signs of clinical failure, with conversion to reverse TSA due to rotator cuff deficiency. Clinical outcome measures (Penn Shoulder Score, shoulder range-of-motion) were not significantly worse in the remaining patients with loosening.

**Discussion:** Postoperative 3-D CT imaging analysis following TSA identified changes in glenoid component position over time not detectable with standard imaging methods. Evidence of subclinical component loosening was present in 32% (6/19) of the current patient cohort, with central peg osteolysis and an increase in HSA-SI associated with component loosening; suggesting rotator cuff dysfunction as a potential contributing factor. Further follow-up and larger patient cohorts are needed to determine the long-term clinical impact of these findings, as well as the anatomic, prosthetic, and surgical factors that most strongly correlate with the development of glenoid component loosening over time. A clearer understanding of these factors will lead to the development of best practices, as well as new and innovative surgical tools, techniques, and implant designs that will maximize implant survival over time.

**Significance:** Postoperative 3-D CT imaging following total shoulder arthroplasty identified changes in glenoid component position over time not detectable on plain radiographs, including subclinical loosening.

![Figure 1](image1.png)

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