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# Glenoid subchondral bone density distribution in male total shoulder arthroplasty subjects with eccentric and concentric wear

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**Background:** Glenoid component loosening in total shoulder arthroplasty may be prevented by component placement on a congruent and adequate bony surface. Glenoid subchondral bone density (SBD) variability may be correlated with this concept. This study analyzed the 3-dimensional distribution of glenoid SBD in total shoulder arthroplasty patients with osteoarthritis.
**Materials and methods:** Three-dimensional computed tomography osteoabsorptiometry (CT-OAM) was performed in 42 men (21 with eccentric and 21 with concentric wear patterns) with glenohumeral arthritis. Glenoid SBD was measured from the joint surface based on 5 clinically relevant topographic zones. The correlation of the wear pattern with the SBD distribution was investigated.
**Results:** The glenoid subarticular layers could be separated into distinct regions: calcified cartilage ($\leq$1.5 mm), subchondral plate (2-4.5 mm) and cancellous bone ($\geq$5 mm). There were significant differences in SBD among these layers within and between patients with concentric and eccentric wear patterns. In concentric glenoids, the SBD distribution was homogeneous, with greater mineralization in the central zone, 1,749.1 $\pm$ 162.3 Hounsfield units (HU) (at 2.5 mm), compared with the posterior, anterior, and superior zones ($P < .001$). In the eccentric group, the SBD distribution was inhomogeneous. Mineralization was greatest in the posterior zone, 1,739.0 $\pm$ 172.6 HU (at 2.5 mm), followed by the inferior zone, 1,722.1 $\pm$ 186.6 HU (at 3 mm).
**Conclusion:** This study represents the first study using CT-OAM to evaluate the 3-dimensional SBD distribution of the glenoid vault for different arthritic wear patterns. The study findings indicate that the SBD distribution is dependent on (1) depth from the articular surface, (2) topographic zone, and (3) wear pattern. CT-OAM may be an effective tool to assist in preoperative planning for shoulder arthroplasty.
**Level of evidence:** Basic Science, Anatomy, Imaging.


**Keywords:** Shoulder; glenoid; total shoulder arthroplasty; osteoarthritis; osteoabsorptiometry; glenoid wear patterns; loosening

This study was determined to be exempt from review by the Western Institutional Review Board.

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Despite the recent advances in total shoulder arthroplasty (TSA) over the past 3 decades, component survivorship remains of paramount concern, with glenoid component loosening as the leading cause of long-term failure.[1] This has spurred significant research into the reasons for glenoid loosening. Recently, Walch et al[14] reported a 32% incidence of glenoid loosening in TSA patients with primary glenohumeral osteoarthritis with a minimum of 5 years' follow-up. In addition, they identified 3 principal patterns of glenoid component migration: superior tilting, subsidence, and posterior tilting.

In analyzing the cause for early glenoid loosening and failure, it has been suggested that reaming of the glenoid subchondral bone may cause structural weakness[4] and that preservation of subchondral bone is key to achieve optimal glenoid component support necessary to resist the compressive and shear forces that occur in vivo.[14] Of particular concern is how to deal with cases of asymmetric glenoid erosion, which usually occurs posteriorly and can be identified on a computed tomography (CT) scan in the axial plane. One surgical option is to ream the glenoid until a uniform surface is achieved so that the glenoid component can rest evenly on the bone. However, excessive reaming to correct significant asymmetric erosion can lead to violation of the subchondral bone and penetration into the glenoid vault, with the potential for early failure of the component.[3] Maximizing the osseous support of the glenoid component is therefore desirable, particularly in the superior and posterior aspects, where the greatest stresses are experienced during arm elevation.[12]

Three-dimensional computed tomography osteoabsorptiometry (CT-OAM) is a noninvasive 3-dimensional (3D) method to analyze the density of the subchondral bone plate in vivo.[7] In comparison with conventional methods of CT densitometry, which calculates an absolute value for bone density in a larger area, CT-OAM is capable of isolating and analyzing the differences in relative density around a defined joint surface, such as the glenoid.[8] Because the overall success of shoulder arthroplasty is partly dependent on the intrinsic properties of the underlying glenoid subchondral bone plate, 3D qualitative analysis of the glenoid bone stock would provide valuable information in further understanding methods that could improve survivorship in TSA. Despite numerous studies published on the subchondral bone density (SBD) distribution,[5,7,10] the SBD distribution of the osteoarthritic glenoid, particularly in surgical cases, has not been analyzed previously.

The purpose of this study is to analyze the glenoid SBD distribution in patients who underwent TSA with a primary diagnosis of osteoarthritis. We hypothesize that the depth of the subchondral bone plate in the diseased glenoid can be quantified using CT-OAM and, furthermore, that different glenoid wear patterns display unique SBD distributions. Moreover, we intend to develop a 3D methodology capable of quantifying the SBD distribution of the glenoid in vivo, which may allow a better understanding of pathology and provide a better rationale for treatment.

## Materials and methods

### Study group

Eighty-six preoperative CT scans of male patients (age range, 60-69 years) who underwent TSA for primary osteoarthritis that met the inclusion criteria were pooled from the patient database of the senior author. The exclusion criteria were age younger than 60 years or greater than 69 years, as well as female patients. To control for age and gender effects, we decided a priori to include only male subjects aged in their 60s. The age group selected represents the median group of patients treated with arthroplasty by the senior author. Additional exclusion criteria included any diagnosis other than primary glenohumeral osteoarthritis and prior shoulder surgery. Patients were then categorized into concentric or eccentric glenoid wear pattern type according to a modified Levine classification using the preoperative CT scans (as detailed in the "Evaluation of glenoid wear pattern" section).

### CT examination

All CT scans were acquired with a GE Lightspeed QZ/i helical scanner (GE Healthcare, Waukesha, WI, USA) in the supine position. CT images were acquired in an axial view with the following scanning parameters: 1.25-mm contiguous slices; pixel size, 0.395 mm; 120 kV; 350 mA; 20-cm field of view; and 512 $\times$ 512 matrix through the shoulder joint. The images were stored in Digital Imaging and Communications in Medicine (DICOM; National Electrical Manufacturers Association, Rosslyn, VA, USA) format and then transferred to computers for analysis.

### Evaluation of glenoid wear pattern

Initially, we performed a reliability analysis on the Walch and Levine glenoid wear classification systems to determine which was most appropriate for our purposes. The Walch classification is commonly used in orthopaedic literature and divides wear into 3 types based on wear symmetry and the amount of glenoid retroversion. The Levine classification is a binary classification that assesses glenoid wear as either concentric or nonconcentric.[6] We modified the original Levine classification for this study by using preoperative CT assessment in the axial plane, instead of plain radiographs and intraoperative assessment. For the reliability analysis, 3 independent orthopaedic surgeons classified 27 randomized, blinded CT images of patients with primary osteoarthritis with both the Walch and modified Levine classifications. By use of the Cohen κ, the Walch classification showed a lower interobserver and intraobserver reliability ($\kappa = 0.54$ and $\kappa = 0.62$, respectively) than the modified Levine classification ($\kappa = 0.60$ and $\kappa = 0.70$, respectively). Resultantly, we decided to use the modified Levine classification for our study.

Thereafter, 2 fellowship-trained orthopaedic shoulder and elbow surgeons classified the glenoids, using the original 86 preoperative CT scans, as showing eccentric or concentric wear