Humeral Stress Shielding and Adaptive Changes at a Mean of 7 Years After Anatomic Shoulder Arthroplasty: What Is the Clinical Significance and With What Are They Associated?

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Introduction: While stress shielding and adaptive changes around the humeral component are often observed after shoulder arthroplasty, clinical significance and potential causative factors have not been well elucidated. These radiographic changes have not been studied well at mid-term follow-up. This study assessed stress shielding and adaptive changes around the humeral component of anatomic total shoulder arthroplasty (TSA) and hemiarthroplasty (HA) at minimum 4-year follow up to answer three questions:

1) Are surgical technique or arthroplasty type associated with patterns of stress shielding, adaptive changes?
2) What is the clinical significance of humeral stress shielding and adaptive changes in HA and TSA?
3) Are the patterns and clinical significance of stress shielding and adaptive changes associated with high-grade glenoid component radiolucency?

Methods: Patients who underwent HA and TSA with minimum 4-year radiographic follow-up were identified from an institutional database. All procedures were performed using a traditional-length, smooth stem implanted with the goal of a low filling ratio and fixed with impaction auto-grafting. Metaphyseal (MFR) and diaphyseal filling ratios (DFR) were assessed on 6-week radiographs. The most recent comparable axillary and AP radiographs were compared to the 6-week radiographs to assess zones of humeral stress shielding/adaptive changes, pedestal formation, component shift, and progressive radiolucencies. In addition, glenoid component central peg osteolysis and peripheral peg radiolucencies were assessed. The clinical outcomes of interest were revision for humeral fixation failure, Simple Shoulder Test (SST) score, and percent of maximum possible improvement of SST (%MPI).

Results: 170 patients met the study criteria, including 91 TSA and 79 HA. The mean radiographic and clinical follow-up was 7.0 years [interquartile range (IQR), 5.3 to 8.6 years]. No patients were revised for loose humeral components during the study period.

- Influence of technical factors and arthroplasty type on patterns of stress shielding and adaptive changes**:** The frequency of changes in each zone were similar between HA and TSA (**Table 1**). The mean MFR was higher in patients with ≥3 zones of changes (52% versus 47%; $p < 0.001$) and calcar osteolysis (51% complete vs 49% partial vs. 47% none; $p = 0.051$). The mean DFR was not different based on the presence of adaptive changes or calcar osteolysis.
- Clinical significance of stress shielding/adaptive changes in HA versus TSA: Patients having TSA with partial or complete calcar osteolysis had lower final SST than those without (Figure 1). Patients having TSA with radiographic changes also had lower mean final SST than those without (Figure 1). By contrast, these effects were not noted in patients who underwent HA.
- Influence of glenoid radiolucency on the patterns and clinical significance of stress shielding/adaptive changes: Patients with high-grade radiolucency around the glenoid component had a greater frequency of changes in ≥3 zones and calcar osteolysis (**Table 1).** In patients with the same extent of radiographic changes around the humeral component, the presence of high-grade glenoid radiolucencies was associated with a lower mean SST than patient without high-grade glenoid component radiolucency (**Figure 1**). This may suggest an influence of factors associated with glenoid component loosening—such as polyethylene, bone or cement debris and inflammatory response to loosening—on humeral radiographic findings.

Conclusion:

- Higher metaphyseal filling ratios are correlated with stress shielding/adaptive changes.
- Changes around the humeral component were associated with less favorable clinical outcomes for patients having TSA but not those having HA.
- Stress shielding/adaptive changes around the humeral component were associated with less favorable clinical outcomes in the presence of high-grade glenoid radiolucency at a mean 7-year follow-up. This may suggest an influence of factors inherent to glenoid component loosening on humeral radiographic findings and the bone-implant interface.

Table I. Frequency of Humeral Radiographic Findings					
Calcar Resorption	***All***	***Hemi***	***TSA***	***Loose Glenoid***	
				Yes	*No*
Complete	4%	3%	5%	18%	0%
Partial	28%	25%	30%	32%	32%
None	68%	72%	65%	50%	68%
Greater Tuberosity Resorption					
Complete	0%	0%	0%	0%	0%
Partial	28%	30%	25%	29%	32%
None	72%	70%	75%	71%	68%
Pedestal Formation	39%	41%	37%	43%	29%
Shift or Subsidence	15%	12%	15%	18%	11%
Adaptive/resorptive changes (≥3 zones)	22%	28%	17%	11%	27%

"Loose" was defined as either a complete lucency around the central peg or Lazarus grade 3 or higher.
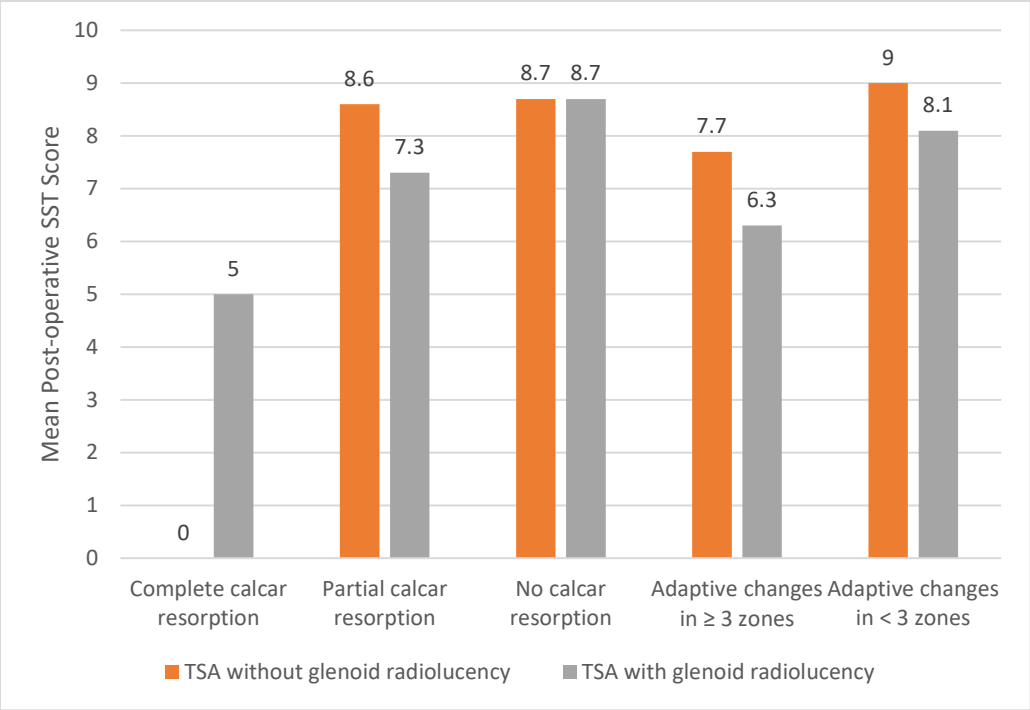
Figure 1: Correlation of TSA humeral radiographic findings with SST score based on presence of glenoid radiolucency.