## Glenoid Component Shift Commonly Occurs Without Evidence of Radiographic Implant Loosening Following Anatomic Total Shoulder Arthroplasty: Minimum 5-Year Threedimensional Computed Tomography Analysis

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INTRODUCTION: Glenoid component loosening is the most common long-term complication following anatomic total shoulder arthroplasty (aTSA). However, accurate determination of component position over time using routine imaging has been limited, with the relationship between implant position and loosening still not well defined. The purpose of this study was to evaluate glenoid component position and radiolucency over time using three-dimensional computed tomography (3D CT) analysis with minimum 5-year follow-up.

METHODS: A series of 152 patients with advanced glenohumeral osteoarthritis undergoing aTSA with a polyethylene anchor peg glenoid component were prospectively enrolled for sequential 3D CT analysis; including preoperative CT1, early postoperative CT2 within 3 months of surgery, and postoperative CT3 at minimum 2-year follow-up (mean  $2.3\pm0.4$  years). 121 patients subsequently returned for postoperative CT4 at minimum 5-year follow-up (mean  $6.6\pm0.9$  years). Glenoid component shift was defined as a change in component version or inclination  $\geq 3^{\circ}$  from CT2 to CT3, CT3 to CT4, or CT2 to CT4. Glenoid component medialization was defined as  $\geq 1$  mm of component medialization from CT2 to CT3, CT3 to CT4, or CT2 to CT4. Glenoid component central peg osteolysis (CPO) was assessed on CT3 and CT4. The relationship between component shift and CPO was evaluated, with statistical comparison made between patients with and without CPO using Kruskal-Wallis tests for continuous variables and significant p-value<0.05.

At minimum 2-year follow-up, 78/152 (51%) patients showed glenoid component shift. Increased inclination was the most common direction of shift, occurring in 76% (59/78) of shift cases (**Figure 1**), while increased retroversion occurred in 31% (24/78) of shift cases. 17/152 (11%) patients showed glenoid component medialization, with 15/17 (88%) of these cases also demonstrating component shift.

At minimum 5-year follow-up, 72/121 (60%) patients showed glenoid component shift. Increased inclination was again the most common direction of shift, occurring in 85% (61/72) of shift cases, while increased retroversion occurred in 33% (24/72) of shift cases. 11/121 (9%) patients showed glenoid component medialization, with 10/11 (91%) of these cases also demonstrating component shift.

CPO was present in 19/152 (13%) patients at minimum 2-year follow-up, with 15/19 (79%) of the CPO cases demonstrating component shift. Similarly, CPO was present in 11/121 (9%) patients at minimum 5-year follow-up, with 10/11 (91%) of the CPO cases demonstrating component shift. However, most cases of glenoid component shift occurred without CPO (81%, 63/78 at minimum 2-year follow-up and 86%, 60/70 at minimum 5-year follow-up). Cases with CPO had significantly greater component shift in absolute inclination, great component shift in combined absolute version and inclination, and greater component medialization than cases without CPO at both minimum 2-year and 5-year follow-up (**Table 1**).

Several patterns of glenoid component shift were seen when looking across the 3 different time intervals (CT2-CT3, CT3-CT4, CT2-CT4). The most common pattern was early implant shift from 0 to 2 years (CT2-CT3) with or without further shift (66% of shift cases). 9/11 (82%) cases with CPO at minimum 5-year follow-up occurred in patients that had 0 to 2 year implant shift (CT2-CT3) with or without further shift. Similarly, 9/11 (82%) cases with component medialization at minimum 5-year follow-up occurred in patients that had 0 to 2 year implant shift (CT2-CT3) with or without further shift. DISCUSSION AND CONCLUSION:

Postoperative 3D CT analysis demonstrates glenoid component shift commonly occurs following aTSA, with 51% of cases showing shift at minimum 2-year follow-up and 60% of cases demonstrating shift at minimum 5-year follow-up. The most common pattern of implant movement was shift at early follow-up (0 to 2 years) with or without further shift, and increased inclination was the most common direction of shift. Implant shift was found to occur in two patterns: one with seemingly adaptive bone remodeling (without CPO) and one with maladaptive bone remodeling (with CPO). Most cases of glenoid component shift (81% at 2 years, 86% at 5 years) showed no CPO, consistent with a stable implant demonstrating potential adaptive bone remodeling. In contrast, cases with CPO (13% at 2 years, 9% at 5 years) had larger absolute component shifts and more component medialization over time, findings concerning for early implant loosening and subsidence. CPO cases most commonly occurred in patients with shift at early follow-up (0 to 2 years). These implant changes cannot be detected on standard postoperative plain radiographs and require 3D CT analysis to measure. Identifying patient, surgical, and implant factors associated with glenoid component migration and potential adaptive bone remodeling will be studied in further analysis of this patient cohort.



Figure 1. Example of shift of the glenoid component at minimum 2-year follow-up. Digital templates of the glenoid and humeral head component positions from the immediate postoperative CT (red templates) and the minimum 2-year follow-up CT (green templates) are superimposed on a representative coronal image from the minimum 2-year follow-up CT to demonstrate the glenoid component shift into increased inclination. In this case, the component shifted into 8° more superior inclination between the two CT scans.

	CPO	No CPO	P-value
Minimum Two-Year Follow-Up, CT2- CT3 (n=152)	n=19 (13%)	n=133 (87%)	-
Absolute Glenoid Component Version Change (degrees)	2.6° [1.0,3.6]	1.7° [0.70,2.8]	0.096
Absolute Glenoid Component Inclination Change (degrees)	4.2° [2.0,7.9]	2.0° [1.0,3.5]	<0.001
Combined Absolute Glenoid Component Version and Inclination Change (degrees)	6.2° [4.4,11.4]	3.9° [2.0,5.7]	<0.001
Glenoid Component Medialization (mm)	-0.80 mm [-1.2,-0.20]	0.00 mm [-0.10,0.20]	<0.001
Minimum Five-Year Follow-Up, CT2- CT4 (n=121)	n=11 (9%)	n=110 (91%)	-
Absolute Glenoid Component Version Change (degrees)	2.8° [1.1,3.9]	2.0° [1.0,3.0]	0.298
Absolute Glenoid Component Inclination Change (degrees)	4.2° [3.2,15.6]	2.8° [1.1,4.0]	0.002
Combined Absolute Glenoid Component Version and Inclination Change (degrees)	8.1° [6.5,18.2]	4.6° [3.0,7.2]	0.001
Glenoid Component Medialization (mm)	-0.63 mm [-1.1,0.02]	0.12 mm [-0.24,0.42]	0.013

Table 1. Comparison of Glenoid Component Shift and Joint Line Medialization in Cases With and Without Central Peg Osteolysis (CPO). Patients underwent sequential CT imaging at 3 postoperative time points: within 3 months of surgery (CT2), at minimum 2-year follow-up (CT3), and at minimum 5-year follow-up (CT4). Glenoid component shift was defined as a change in glenoid component reseion or inclusion ≥ 9<sup>+</sup> from CT2 to CT3, CT3 to CT4, or CT2 to CT4. Glenoid component medialization was defined as ≥ 1 mm of component medialization from CT2 to CT3, CT3 to CT4, or CT2 to CT4. Median [interquartile range], N (%)