



# Midterm results of anatomic total shoulder arthroplasty with a third-generation implant



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**Background:** Anatomic total shoulder arthroplasty (TSA) provides reliable, reproducible, and durable results; however, outcomes of many modern TSA systems are lacking. The present study reports early to midterm results of a third-generation TSA system using a traditional-length press-fit humeral stem and cemented glenoid.

**Methods:** A retrospective review was conducted of TSA patients with minimum 2-year clinical follow-up. Patient-reported outcome measures, including Simple Shoulder Test, American Shoulder and Elbow Surgeons Total, visual analog scale for pain, 12-Item Short Form Health Survey, and Single Assessment Numeric Evaluation, as well as measured active motion (forward elevation, external and internal rotation), were recorded at preoperative and postoperative intervals. Preoperative midglenoid axial computed tomography scans were used to evaluate eccentric glenoid wear, humeral head subluxation, and glenoid version. Most recent postoperative radiographs were used to evaluate glenoid loosening, humeral loosening, lesser tuberosity union, and medial calcar resorption. Patient satisfaction at final follow-up was reported as excellent, good, satisfied, or unsatisfied.

**Results:** There were 267 patients who met inclusion criteria, with a mean age of 70.9 years and mean clinical follow-up of 47 months. Average glenoid retroversion was 9.7°, and 27% had eccentric glenoid wear. At final follow-up, measured motion and nearly all patient-reported outcome measures showed significant improvements, with 75.6% of patients rating their satisfaction as excellent. No patient was considered “at risk” for humeral stem loosening. Glenoid radiolucencies were seen in 13.5% of shoulders (7 gross loosening). Five patients were revised to reverse TSA.

**Conclusion:** TSA using a third-generation traditional-length press-fit stem and cemented glenoid provides excellent early to midterm outcomes with low rates of loosening and high rates of excellent satisfaction.

**Level of evidence:** Level IV; Case Series; Treatment Study

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Anatomic total shoulder arthroplasty (TSA) has repeatedly been shown to provide reliable, reproducible, and durable results for patients with end-stage arthritis.<sup>7,18,31</sup> Long-term outcomes have been reported using early generation

implants<sup>4,22,31,34,37</sup>; however, a number of innovations that have influenced patient outcomes have been developed since these initial reports. Humeral and glenoid TSA components have both undergone design improvements. Humeral stem innovations have included features that support anatomic reconstruction, osseous biologic fixation, and shorter length components. Glenoid component improvements have focused on improved instrumentation, enhanced fixation, and increased polyethylene durability. The innovations in TSA are supported by limited studies reporting successful early outcomes<sup>1,6,11,12,21,25</sup>; however, outcomes have not been reported for all prosthetic designs.

The purpose of this study is to report the early to midterm results of a high-volume single surgeon experienced with a third-generation TSA system using a traditional-length press-fit humeral stem with a modular humeral head and cemented glenoid. This stem features innovation that supports cementless fixation and osseous integration, including a tapered proximal body, fins, and proximal plasma spray finish. To date, no study has focused on the postoperative outcomes and radiographic findings using this prosthetic design. The hypothesis is that this anatomic TSA system can provide improvements in pain and patient-reported outcome measures (PROMs) with a low rate of complication and high levels of satisfaction.

## Materials and methods

A retrospective review of an Institutional Shoulder Surgery Repository was performed to identify all patients treated with primary anatomic TSA between April 2009 and October 2015. Inclusion criteria identified consented patients treated with a primary third-generation TSA system (DJO Turon, Austin, TX, USA) with complete preoperative data and a minimum of 2-year follow-up data. Patients undergoing revisions and those treated with other TSA implant systems were excluded.

As part of the standard protocol for the Institutional Shoulder Surgery Repository, PROMs were routinely collected before surgery, at 3, 6, and 12 months after surgery, and annually thereafter. When patients were unable to return for follow-up evaluation, an automated e-mail was generated with a secure link to complete the PROMs surveys using a Health Insurance Portability and Accountability Act–protected web-based portal.<sup>33</sup> PROMs collected included the Simple Shoulder Test, American Shoulder and Elbow Surgeons Total (ASES), visual analog scale (VAS) for pain, Single Assessment Numeric Evaluation (SANE) and 12-Item Short Form Health Survey Mental and Physical Component Scores. At each visit, the patient's best effort range of motion was measured goniometrically and recorded in the repository. Measurements included forward elevation, external rotation, and internal rotation, which was measured as the highest midline segment of the back that could be reached.<sup>32</sup> Overall patient satisfaction with the procedure was reported as excellent, good, satisfied, or unsatisfied.

All TSA procedures were performed by the same surgeon using a deltopectoral approach. The subscapularis was taken down using a subscapularis peel or fleck lesser tuberosity osteotomy based on the preoperative degree of internal rotation contracture (peel used in cases of less than neutral, passive external rotation).

A press-fit humeral component was used for all cases. Stem size was selected based on the smallest broach size that achieved rotational stability. Bone graft from the humeral head was morselized and packed into the humeral canal before stem implantation. The glenoid was prepared using standard noncannulated instrumentation with a goal of at least 80% backside concentric support of the glenoid component, similar to what has been advocated by Orvets et al<sup>20</sup>. Asymmetric reaming of the glenoid was typically used for shoulders with eccentric glenoid wear, partially correcting preoperative retroversion.

All glenoid components were cemented using standard cementation technique injected under pressure using a syringe, with additional cement placed on the backside of the glenoid component before implantation. A keeled glenoid component was used when the glenoid vault was narrow.

Postoperatively, all patients were managed with the same rehabilitation protocol consisting of a shoulder immobilizer and therapy focused on pendulum exercises only for the first 6 weeks, followed by a self-directed active-assisted stretching program. Strengthening and lifting were delayed for 3 months.

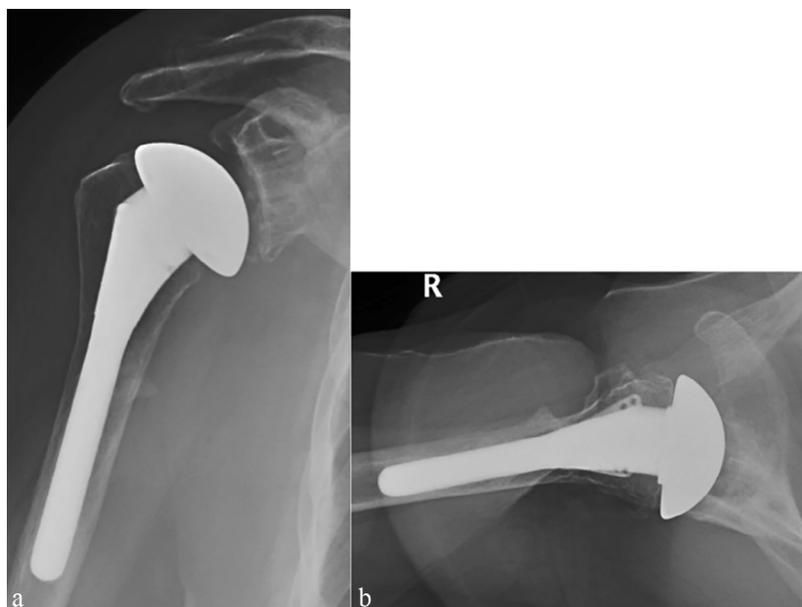
A preoperative radiographic analysis was performed using a consensus of at least 2 trained reviewers and subsequent confirmation by the senior author (JCL). Measurements using preoperative midglenoid axial computed tomography (CT) scans were used to classify all presurgical glenoid pathology. Glenoids were classified as concentric or eccentric using the Levine classification.<sup>15</sup> The humeral head subluxation index was calculated using the glenoid-based technique described by Walch et al.<sup>35</sup> Glenoid version was calculated using the Friedman angle.<sup>8</sup> Glenoids with eccentric wear were further evaluated for the percentage of neoglenoid (ratio of the neoglenoid to the entire glenoid) and the neoglenoid version using the Friedman angle based on the neoglenoid.

Postoperative radiographs were reviewed using a similar consensus method. The most recent scapular anterior-posterior and axillary lateral radiographs were assessed for glenoid polyethylene loosening,<sup>14</sup> humeral stem loosening,<sup>29</sup> lesser tuberosity union,<sup>27</sup> and medial calcar resorption.<sup>5</sup> The most recent radiographs were also used to distinguish diaphyseal press-fit from metaphyseal press-fit. Diaphyseal press-fit was defined as complete filling of the intramedullary canal with the humeral stem (Fig. 1).

Comparisons of preoperative to postoperative change in PROMs and measured motion were made. Additional comparisons of preoperative radiographic findings and postoperative PROM improvement were made between patients observed to have postoperative glenoid radiolucencies and those patients without. Outcomes were further compared among those with CT evidence of preoperative eccentric wear. Means were compared using independent samples *t* tests (Excel Analysis ToolPak, version 15; Microsoft, Redmond, WA, USA) with a *P* value set at .05.

## Results

Of the 320 patients with preoperative data treated during the study period, 267 (83%) met inclusion criteria of minimum 2-year follow-up. There were 132 men and 135 women, with a mean age of 70.9 years (range, 32-88 years). TSA was indicated in 238 patients for end-stage osteoarthritis, in 26 for inflammatory arthritis, and in 3 for avascular necrosis. Pegged glenoid components were used in 253 patients, and keeled



**Figure 1** (a) Anterior-posterior and (b) axillary lateral radiographs of 76-year-old right shoulder, 7 years after the index operation. A diaphyseal press-fit was achieved, with complete filling of the intramedullary canal with the humeral stem.

components in 14 patients. The average humeral stem size was 10 mm, and the average humeral head size was 46 mm. Mean clinical follow-up was 47 months (range, 24-101 months), and mean radiographic follow-up was 33 months (range 1.4-101 months).

Preoperative midglenoid axial CT scan analysis revealed an average glenoid retroversion of  $9.7^\circ \pm 8.9^\circ$  (range,  $37.8^\circ$  retroversion to  $15.7^\circ$  anteversion), with an average humeral subluxation index of 52.3% (range 21.1%-78.8%). Eccentric glenoid wear was identified in 72 patients (27%). These patients were found to have an average neoglenoid retroversion of  $12.3^\circ \pm 8.2^\circ$  (range,  $30.9^\circ$  retroversion to  $2.9^\circ$  anteversion), with an average neoglenoid percentage of  $62.0\% \pm 10.0\%$  (range, 31.9%-94.4%). The preoperative midglenoid axial CT scan measurements are listed in Table I.

Significant improvements were observed for all PROMs and measured motion (Table II). This included significant improvements in Simple Shoulder Test (5.90), ASES Total (50.85), VAS pain (5.45), and SANE (42.04). Forward elevation improved an average of  $43^\circ$ , external rotation by  $28^\circ$ , and internal rotation by 97% (3.7% to 7.3%). Satisfaction with the outcome was rated as excellent by 75.6% of patients, with only 3% of patients rating an unsatisfactory outcome.

Postoperative radiographic review identified glenoid radiolucency in 13.5% of shoulders (36 patients), with 7 showing gross loosening. Comparisons of preoperative CT findings between those with and without glenoid loosening revealed no significant differences for any measured variables (Table III). However, those found to have glenoid radiolucent lines had significantly longer radiographic follow-up (49.5 vs. 29.6 months,  $P < .001$ ). Details of the 7 patients with gross loosening are highlighted in Table IV. Resorption of the calcar was found in 158 patients (59%). No patient was consid-

**Table I** Preoperative and postoperative radiographic measurements

Radiographic measurement	Mean	SD	Range
<b>Preoperative CT findings</b>			
Subluxation index, %	52.3	8.2	21.1 to 78.8
Glenoid version, °	-9.7	8.9	-37.8 to 15.7
Version of neoglenoid, °	-12.3	8.2	-30.9 to 2.9
Neoglenoid, %	62.0	10.0	31.9 to 94.4
		No.	%
<b>Postoperative radiographs</b>			
Any glenoid loosening (Lazarus grade 1-5)		36	13.5
Gross glenoid loosening (Lazarus grade 5)		7	2.5
<b>Lesser tuberosity osteotomy</b>			
Complete union		143	75.6
Nondisplaced nonunion		16	8.4
Displaced nonunion		14	7.4
Not seen		16	8.4
Medial calcar resorption		158	59.6

SD, standard deviation; CT, computed tomography.

ered "at risk" for humeral stem loosening, and no humeral stem subsidence was observed.

There were 9 cases (3.3%) of a diaphyseal press-fit, with the remainder of the humeral stems obtaining metaphyseal fixation (96.7%). Of the 189 shoulders with lesser tuberosity osteotomy (71% of all TSAs), a complete union was noted in 76% of patients. Nondisplaced nonunions were seen in 16 patients, and displaced nonunions were seen in 14 patients (Table I).

Subgroup analyses of patients with preoperative CT evidence of eccentric glenoid wear revealed worse overall improvement in pain and functional scores. Significant

**Table II** Preoperative to postoperative improvement in patient-reported outcome measurements and measured motion

Variable	Pre-op	Post-op	Mean improvement	P value
Patient-reported outcomes				
SST	3.3	9.3	5.9	<.001
ASES	30.2	81.3	50.9	<.001
VAS pain	6.7	1.3	5.5	<.001
MCS	53.5	55.0	1.5	.11
PCS	34.9	42.0	7.1	<.001
SANE	36.7	76.9	42.0	<.001
Measured active motion				
Elevation, °	94	138	43	<.001
External rotation, °	20	48	28	<.001
Internal rotation, points*	3.7	7.3	3.5	<.001
Satisfaction				
Excellent	202 (75.6)			
Good	39 (14.6)			
Satisfactory	18 (6.7)			
Unsatisfactory	8 (3.0)			

SST, Simple Shoulder Test; ASES, American Shoulder and Elbow Surgeons; VAS, visual analog scale; MCS, 12-item Short Form Health Survey Mental Component Score; PCS, 12-item Short Form Health Survey Physical Component Score; SANE, Single Assessment Numeric Evaluation. Data are presented as the mean value or as number (%).

\* Internal rotation conversion scale: buttock to greater trochanter (2 points); sacrum to L4 (4 points); L3-L1 (6 points); T12-T8 (8 points); T7-T1 (10 points).

**Table III** Comparison of patients with postoperative glenoid radiolucency to those without postoperative glenoid radiolucency

Radiographic measurement	Glenoid radiolucency	No glenoid loosening	P value
	(n = 36)	(n = 231)	
	Mean	Mean	
Preoperative CT findings			
Subluxation index, %	51.5	52.4	.513
Glenoid version, °	-11.6	-9.4°	.169
Concentric glenoids, %	75	73	.786
Version of neoglenoid, °	-14.9	-12.0	.529
Neoglenoid, %	59.0	62.3	.835
Goutallier classification			
Supraspinatus	2.1	2.2	.703
Infraspinatus	0.7	0.7	.692
Teres minor	0.6	0.6	.964
Subscapularis	1.3	1.0	.18
Postoperative radiographs			
Radiographic follow-up, mo	49.5	29.6	<.001

CT, computed tomography.

differences in overall improvement of ASES (53.2 vs. 44.6;  $P = .01$ ), VAS pain (5.7 vs. 4.8;  $P = .04$ ), and forward elevation (46 vs. 35;  $P = .02$ ) were observed (Table V).

Five patients required revision to a reverse shoulder arthroplasty. One of these patients developed a late infection and was revised at 5 years to a reverse shoulder as a staged operation with an antibiotic spacer. One patient with preoperative eccentric glenoid wear developed painful posterior instability and gross glenoid loosening 7.5 years after TSA (Fig. 2). Three additional patients developed rotator cuff tears with resulting pseudoparesis and were revised at 2, 2, and 3

years postoperatively. None of these patients had full-thickness tears at the time of primary TSA surgery.

## Discussion

The current study reports successful outcomes after primary anatomic shoulder arthroplasty using a third-generation traditional-length press-fit stem and cemented glenoid component. Significant improvement in pain and functional outcomes, high rates of excellent patient satisfaction, and low

**Table IV** Details of patients with gross glenoid loosening

Patient	Preoperative computed tomography scan			Post-operative radiographic findings		Revision indication
	Glenoid retroversion (°)	Subluxation index (%)	Levine classification	Radiographic follow-up (mo)	Lesser tuberosity osteotomy	
1	22.8	46.9	2	84.5	Union	Not applicable
2	21.7	47.7	2	73.3	Union	Not applicable
3	21.4	53.0	1	88.0	Union	Not applicable
4	18.1	66.8	1	76.6	Union	Not applicable
5	5.3	48.6	1	59.7	Displaced nonunion	Supraspinatus, infraspinatus, subscapularis tear
6	14.5	53.5	2	77.4	Displaced nonunion	Painful loosening with posterior instability
7	5.0	56.1	1	46.0	Displaced nonunion	<i>Cutibacterium acnes</i> * infection

\* *Cutibacterium* (formerly *Propionibacterium*) *acnes*.

**Table V** Comparison of outcomes in patients with preoperative eccentric and concentric glenoid wear

Variable	Concentric glenoid (n = 195)	Eccentric glenoid wear (n = 72)	P value
Patient-reported outcome improvement			
Simple Shoulder Test	6.1	5.3	.16
ASES	53.2	44.6	.01
VAS pain	5.7	4.8	.04
MCS	1.7	0.8	.61
PCS	7.2	6.89	.78
SANE	43.6	37.9	.27
Measured active motion			
Elevation, °	46	35	.02
External rotation, °	30	26	.20
Satisfaction			
Excellent	149 (76.4)	53 (73.6)	
Good	15 (12.8)	14 (19.4)	
Satisfactory	15 (7.7)	3 (4.2)	
Unsatisfactory	6 (3.0)	2 (2.8)	

SST, Simple Shoulder Test; ASES, American Shoulder and Elbow Surgeons; VAS, visual analog scale; MCS, 12-item Short Form Health Survey Mental Component Score; PCS, 12-item Short Form Health Survey Physical Component Score; SANE, Single Assessment Numeric Evaluation. Data are presented as the mean value or as number (%).

rates of loosening were observed at an average of 4 years of follow-up. This study further supports the existing literature in managing patients with end-stage arthritis using anatomic TSA. Furthermore, these results support the use of innovations in humeral stem modularity, biologic stem fixation, and instrumentation that support cemented glenoid component implantation.

Results of early generation anatomic TSA designs demonstrated significant improvements in pain and functional outcomes; however, glenoid loosening rates were often

high.<sup>28,30,31</sup> In treating patient with rheumatoid arthritis, Stewart and Kelly<sup>30</sup> reported glenoid loosening in 27% of cases at 9.5 years, and Sojbjerg et al<sup>28</sup> similarly found radiographic loosening in 42% of cases.<sup>28,30</sup> In a series of patients treated for osteoarthritis, rheumatoid, and traumatic arthritis, Torchia et al<sup>31</sup> reported glenoid radiolucencies in 66% of patients, with 44% showing clear signs of definitive prosthetic loosening.<sup>31</sup> Radiolucent lines have been associated with worse outcomes and remain a concern because glenoid loosening is one of the leading causes of revision.<sup>31,36</sup>

Although the rate of glenoid loosening in the current study is lower than these historical reports, the radiographic follow-up of the current study is much shorter. Longer-term follow-up of patients treated with this third-generation system is needed to help determine whether these innovations have helped to lower glenoid loosening. Innovations in prosthetic design, similar to those seen in the implant used in this series, have focused on more anatomic humeral reconstruction and improved glenoid preparation to decrease the rates of glenoid loosening.<sup>12</sup>

Anatomic reconstruction of the humeral head is felt to result in improved functional outcomes and reduced stress transfer to the glenoid component.<sup>19</sup> With the anatomic variability of the proximal humerus geometry,<sup>2</sup> third-generation humeral stems were developed with modular head sizes and offsets to accommodate anatomic variations.<sup>12</sup> Midterm and long-term results of third-generation modular humeral components have demonstrated a low incidence of radiolucent lines when combined with a nonconforming, radius mismatched glenoid component.<sup>12</sup> This was similarly observed in this study, with glenoid radiolucent lines seen in only 13.5% of patients and only 7 cases of gross loosening (2.6%).

Among the shoulders found to have glenoid radiolucencies, no differences in preoperative version, subluxation, the percentage of concentric glenoids, or rotator cuff fatty infiltration were observed (Table III). However, those with radiolucent lines were found to have a longer radiographic



**Figure 2** (a) Anterior-posterior (AP) and (b) axillary lateral radiographs of 46-year-old man with severe glenohumeral arthritis with eccentric posterior wear and posterior subluxation. Comparison of initial postoperative (c) AP and (d) axillary lateral radiographs and 7-year postoperative (e) AP and (f) axillary lateral radiographs demonstrate posterior subluxation of the humeral component with a grossly loose glenoid.

follow-up. This suggests that radiolucent lines may become more common over time and justifies a subsequent investigation of this patient cohort with long-term follow-up.

Standard nonaugmented glenoid components were used in all cases in this series, including those patients with eccentric glenoid wear (72 patients), high glenoid-based humeral subluxation index (up to 78.8%), and excessive glenoid version (up to 31° retroversion). Although innovations in prosthetic glenoid design have recently focused on augmented glenoid components for the restoration of glenoid version and offset,<sup>23</sup> this series demonstrates an ability to use partial correction with asymmetric reaming to create proper soft tissue balancing during the procedure. Others have reported similar techniques<sup>10,20,26</sup> in managing patients with eccentric wear or excessive retroversion. Nevertheless, significantly worse improvements in overall pain relief and functional scores were observed among patients with eccentric glenoid wear patterns. Further investigation of the subset of patients with eccentric wear is of interest.

Humeral component fixation has evolved over the years, with innovations focused on the achievement of biologic fixation with osseous integration. Initial use of early stems without features that support osseous integration was associated with high rates of humeral component loosening.<sup>28,30,31</sup> During the

same period, studies using cemented components reported low rates of humeral stem loosening.<sup>12,17</sup> Furthermore, a prospective, randomized controlled study of cemented and uncemented humeral components in TSA using an implant not specifically designed for bony ingrowth found improved outcomes with cemented fixation.<sup>16</sup> As prosthetic design improvements focused on creating features to support osseous integration of the humeral component, more recent reports of cementless fixation using standard-length stems, short-length stems,<sup>25</sup> and even stemless components<sup>1,9</sup> have shown low rates of humeral stem loosening with consistent clinical improvements.

The current study observed no case of “at risk” humeral loosening using a humeral component with features supporting biologic osseous integration at the metaphyseal region. With 96.7% of the humeral stems implanted with a metaphyseal press-fit, this study further supports the use of metaphyseal-based cementless fixation for modern anatomic TSA humeral components.

Various methods of subscapularis management have been used in TSA, including subscapularis peel, tenotomy, lesser tuberosity osteotomy, and subscapularis sparing. Although clinically significant differences in outcomes have not been observed universally,<sup>13</sup> several studies have suggested

improved healing and patient outcomes using a lesser tuberosity osteotomy.<sup>3,24</sup> Interestingly, of the patients in this study treated with a fleck lesser tuberosity osteotomy, complete healing was noted in only 76%. Nonetheless, only 5 patients underwent revision surgery, none of whom had isolated subscapularis insufficiency. Further investigation into the outcomes of patients with nonunions of a lesser tuberosity osteotomy is of interest.

Strengths of this study relate to the large series of 267 patients at an average of 4 years of follow-up. This provides ample opportunity to observe complications that may develop in the early to midterm period after anatomic shoulder arthroplasty. As a single-surgeon series, the variability of surgical technique, implant use, and postoperative protocols was well controlled.

However, the results of this study may not extrapolate to the general orthopedic population. An additional limitation of this study relates to the use of a single TSA implant, which limits the conclusions to a specific design. However, given the similar results observed using other modern TSA systems, the results of this study are valuable in supporting the use of third-generation TSA implants.

For many patients, postoperative radiographic follow-up was shorter than clinical outcomes follow-up, because e-mail surveys were likely completed online for patients who were unable to return for routine follow-up. Thus, additional cases of prosthetic loosening or other radiographic findings may have remained undetected. This is highlighted by the observation that patients with glenoid radiolucency had a greater average radiographic follow-up. Long-term follow-up of this patient cohort may highlight further developments of radiolucent lines and the potential effect on outcomes and need for revision.

## Conclusion

Use of a third-generation anatomic TSA with a traditional length press-fit humeral stem and cemented glenoid component results in excellent 4-year functional outcomes with low rates of loosening and high rates of excellent results.

## Disclosures

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