Outcomes After Anatomic and Reverse Shoulder Arthroplasty for the Treatment of Glenohumeral Osteoarthritis

A Propensity Score-Matched Analysis

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Background: Reverse shoulder arthroplasty (RSA) is increasingly being utilized for the treatment of primary osteoarthritis. However, limited data are available regarding the outcomes of RSA as compared with anatomic total shoulder arthroplasty (TSA) in the setting of osteoarthritis.

Methods: We performed a retrospective matched-cohort study of patients who had undergone TSA and RSA for the treatment of primary osteoarthritis and who had a minimum of 2 years of follow-up. Patients were propensity score-matched by age, sex, body mass index (BMI), preoperative American Shoulder and Elbow Surgeons (ASES) score, preoperative active forward elevation, and Walch glenoid morphology. Baseline patient demographics and clinical outcomes, including active range of motion, ASES score, Single Assessment Numerical Evaluation (SANE), and visual analog scale (VAS) for pain, were collected. Clinical and radiographic complications were evaluated.

Results: One hundred and thirty-four patients (67 patients per group) were included; the mean duration of follow-up (and standard deviation) was 30 ± 10.7 months. No significant differences were found between the TSA and RSA groups in terms of the baseline or final VAS pain score ($p = 0.99$ and $p = 0.99$, respectively), ASES scores ($p = 0.99$ and $p = 0.49$, respectively), or SANE scores ($p = 0.22$ and $p = 0.73$, respectively). TSA was associated with significantly better postoperative active forward elevation (149° ± 13° versus 142° ± 15°; $p = 0.003$), external rotation (63° ± 14° versus 57° ± 18°; $p = 0.02$), and internal rotation (≥L3) (68.7% versus 37.3%; $p < 0.001$); however, there were only significant baseline-to-postoperative improvements in internal rotation (gain of ≥4 levels in 53.7% versus 31.3%; $p = 0.009$). The overall complication rate was 4.5% (6 of 134), with no significant difference between TSA and RSA ($p = 0.99$). Radiolucent lines were observed in association with 14.9% of TSAs, with no gross glenoid loosening. One TSA (1.5%) was revised to RSA for the treatment of a rotator cuff tear. No loosening or revision was encountered in the RSA group.

Conclusions: When performed for the treatment of osteoarthritis, TSA and RSA resulted in similar short-term patient-reported outcomes, with better postoperative range of motion after TSA. Longer follow-up is needed to determine the ultimate value of RSA in the setting of osteoarthritis.

Level of Evidence: Therapeutic Level III. See Instructions for Authors for a complete description of levels of evidence.

The dramatic rise in shoulder arthroplasty volume has largely been driven by increased utilization of reverse shoulder arthroplasty (RSA)[1-3]. The use of primary RSA has tripled over recent years, with RSA representing approximately 60% of all shoulder arthroplasty volume as of 2017[1]. Recent evidence projects RSA increasing between 122% to 353% and anatomic total shoulder arthroplasty (TSA) increasing by approximately 50% between 2017 and 2025[2,3]. Additionally, shoulder arthroplasty is increasing at a greater rate (68% to 235%) as compared with total hip (34% to 47%) and knee arthroplasty (22%) between 2017 and 2025[3].

The utilization of RSA relative to TSA may be secondary to expanding indications coupled with favorable clinical outcomes. RSA originally was indicated for rotator cuff tear

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arthropathy; however, it is now also routinely used for various conditions, including primary osteoarthritis[4-9]. TSA is still largely regarded as the gold standard treatment for osteoarthritis[10-12]; however, recent evidence has substantiated the emerging role of RSA[6-9,13]. RSA in the setting of primary osteoarthritis accounts for approximately 33% of all RSA procedures being performed[1]. The increasing role of RSA for osteoarthritis in patients with an intact rotator cuff may be related to the rates of anatomic glenoid component failure and secondary rotator cuff dysfunction observed with longitudinal follow-up after TSA[14-16]. Moreover, large registry studies have demonstrated higher cumulative revision rates after TSA as compared with RSA after both short-term[17] and long-term[18] follow-up.

Given the increased risk of revision surgery[8,17,18] coupled with similar clinical outcomes when comparing RSA and TSA for primary osteoarthritis[8,9,13], there has been an evolving trend toward using RSA for the treatment of osteoarthritis in patients with an intact rotator cuff[1,7,8,13]. Current literature comparing RSA and TSA in the setting of osteoarthritis is limited to smaller, heterogenous studies. The purpose of the present study was to evaluate the clinical outcomes and complications of a consecutive, prospective, matched series of patients undergoing primary RSA or TSA for osteoarthritis. We hypothesized that patient-reported outcome scores would be similar between the groups, with better range of motion in the TSA group.

Materials and Methods

Patient Selection

A retrospective review of a consecutive series of patients in a prospectively maintained institutional database with >75% overall complete follow-up (OBERD) was performed, following approval from the institutional review board, to identify patients who had undergone primary shoulder arthroplasty between 2015 and 2018. All procedures were performed by a single high-volume fellowship-trained shoulder and elbow surgeon (A.J.) at a large private institution. The inclusion criteria were (1) primary TSA or RSA for the treatment of osteoarthritis in the presence of an intact rotator cuff, (2) a minimum clinical follow-up of 2 years, (3) complete preoperative and postoperative functional outcomes scores, and (4) the availability of preoperative advanced imaging (magnetic resonance imaging [MRI] or computed tomography [CT]) to assess glenoid morphology according to the modified Walch classification system[19]. Preoperative MRI scans were reviewed by a musculoskeletal radiologist and the operative surgeon to confirm rotator cuff integrity. The exclusion criteria were (1) a diagnosis other than primary osteoarthritis, (2) the presence of a rotator cuff tear, (3) incomplete clinical follow-up, or (4) a history of ipsilateral shoulder surgery other than an arthroscopic debridement.

Matching

Patients who met the inclusion and exclusion criteria were then 1:1 propensity score-matched[20]. The propensity scores were generated with use of a logistic regression model method incorporating age, sex, body mass index (BMI), preoperative American Shoulder and Elbow Surgeons (ASES) score, preoperative active forward elevation, and Walch glenoid morphology as covariates. The matching process was executed utilizing a greedy, nearest-neighbor matching algorithm, without replacement[20]. A caliper was specified for acceptable matches in order to eliminate the risk of making bad matches if the closest eligible neighbor was far away. The caliper was set as 0.2 times the standard deviation of the logit of the propensity scores among the entire population. Experimentally, 0.2 to 0.5 times the standard deviation of the logit of the propensity score has been recommended as an appropriate caliper to effectively control for variance, with lower values having increased precision in matching[20]. With this matching algorithm, the resulting population size was 134 patients (67 per group).

Surgical Technique

All procedures were performed by the senior surgeon (A.J.), with the patient under general anesthesia. A deltopectoral approach was utilized in all cases. The biceps tendon was tenodesed to the pectoralis major tendon in all cases when it was intact. A lesser tuberosity osteotomy was performed during TSA, whereas a subscapularis peel was used during RSA. Direct intraoperative visual assessment of the rotator cuff was performed in all cases to confirm its integrity. The subscapularis was repaired in all cases with use of an identical technique involving a combination of simple and Mason-Allen transosseous sutures. Patients undergoing TSA were treated with a standard cemented all-polyethylene glenoid component. No augmented anatomic glenoid components were used. Of the patients undergoing TSA, 27 (40.3%) received a DJO AltiVate implant (DJO Surgical), 22 (32.8%) received a Zimmer Anatomical implant and 8 (11.9%) received a Zimmer Sidus stemless implant (Zimmer Biomet), and 10 (14.9%) received an Aequalis Ascend Flex implant (Wright Medical). All patients undergoing RSA had similar implants (AltiVate Reverse; DJO Surgical). A 32 minus 4-mm lateralized glenosphere was used in female patients, whereas a 36-mm neutral lateralized glenosphere was used in male patients as per the senior author's preference. All patients received an uncemented inlay standard-length humeral component. No patient underwent glenoid bone-grafting. All patients underwent similar postoperative rehabilitation, which involved restricted shoulder range of motion in a simple sling for the first 2 weeks followed by gradual and progressive range of motion following a physician-directed protocol without formal physical therapy.

Clinical Outcome Assessment

Patient demographics, including age, sex, and BMI, were extracted from the electronic medical record. Clinical examination was performed at the initial preoperative visit and the most recent postoperative visit by the senior surgeon (A.J.). Active shoulder range of motion, including forward elevation and external rotation with the arm at the side, was assessed with routine use of a goniometer, whereas internal rotation was determined by the uppermost vertebral level of the spine

reached by the thumb of the examined arm. Levels of internal rotation were then categorized as follows: hip to L4 (lower lumbar or less), L3 to T12 (upper lumbar to low thoracic), and T11 or higher (higher than low thoracic). Patient-reported outcome measures (PROMs), including the ASES score, Single Assessment Numeric Evaluation of the Shoulder (SANE) score, and visual analog scale (VAS) for pain, were prospectively recorded preoperatively and at the time of the latest follow-up. All PROMs were analyzed with use of proprietary electronic software (OBERD). Complications and the need for revision surgery were prospectively recorded.

Radiographic Evaluation

Glenoid morphology was assessed independently by 2 fellowship-trained shoulder and elbow surgeons (J.M.K., R.C.) who were blinded from all clinical outcome data. Preoperative radiographs and advanced imaging (MRI and CT) were available for all patients. All patients undergoing TSA had preoperative MRI, and 33 (49.3%) had preoperative CT. Fifty-two patients (77.6%) undergoing RSA had preoperative MRI, and 43 (64.2%) had preoperative CT. Preoperative glenoid morphology was determined by consensus according to the modified Walch classification system[19]. All patients had standardized true anteroposterior (Grashey) and axillary radiographs made at each postoperative visit. The most recent postoperative radiographs at a minimum of 2 years of follow-up were evaluated for signs of glenoid component loosening according to the Lazarus classification system[21]. Similarly, radiographs were evaluated for radiolucent lines around the baseplate or screws, and for evidence of gross shift in position of the component to identify loosening.

Statistical Analysis

Descriptive statistics were determined and expressed as the mean and standard deviation (SD), median with interquartile range, or percentage, as indicated by the data type and distribution. Preoperative and postoperative clinical outcomes were analyzed with statistical tests, including the pooled and unpooled t test, Mann-Whitney U test, and 2-proportion Z test, as indicated by the data type and distribution. Univariate analysis was performed to compare baseline demographic characteristics and glenoid morphology and to quantitively assess the matching balance between groups. Improvements in ASES scores were compared with the threshold minimal clinically important difference (MCID) (10.3 ± 3.3) and substantial clinical benefit (SCB) (25.9 ± 2.9) values for both groups as reported by Simovitch and colleagues[22,23]. The alpha level was set to 0.05 for all tests to estimate significance. All statistical analysis was performed with use of R statistical software (version 1.2.1335; R Foundation for Statistical Computing).

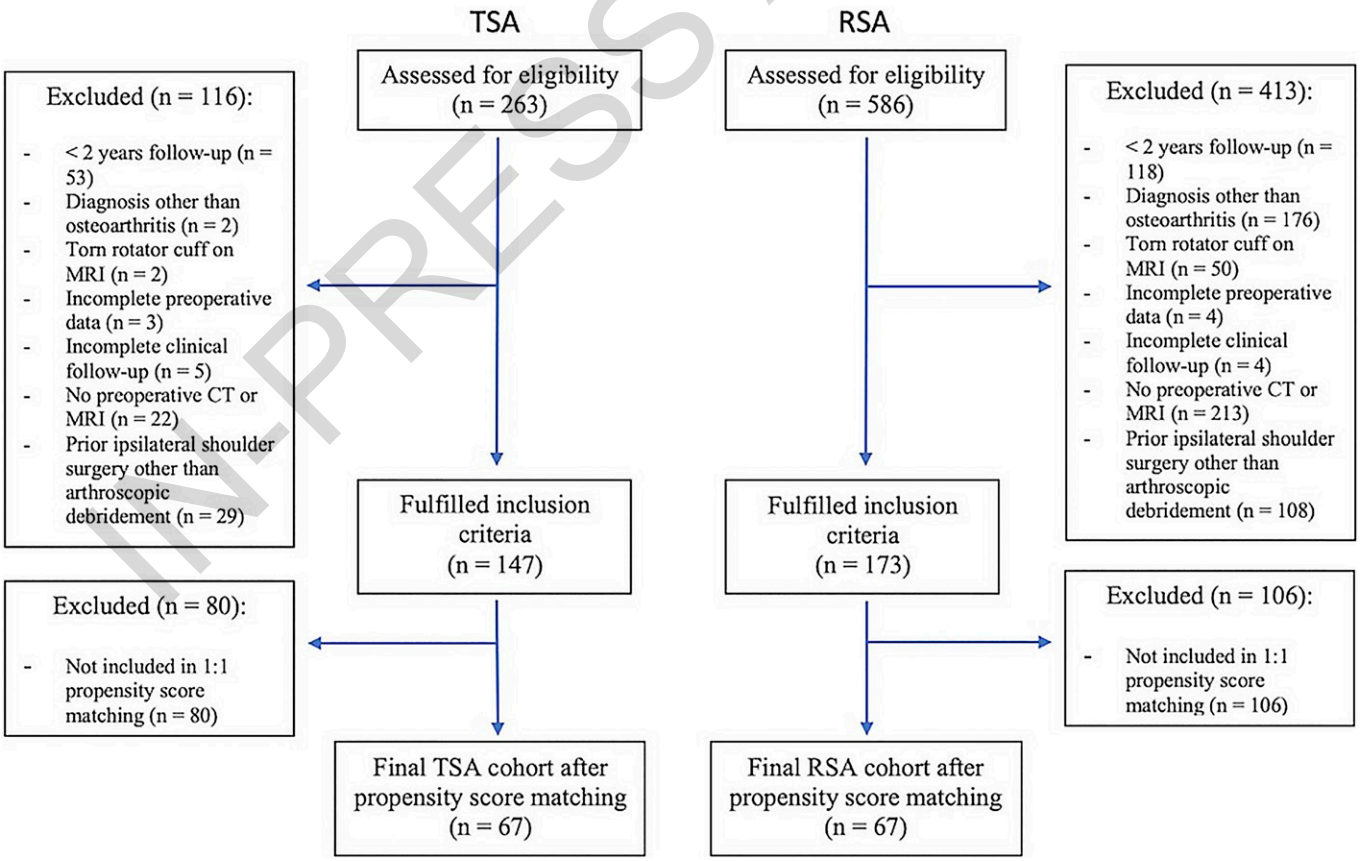

Fig. 1

Flow diagram demonstrating patient inclusion and exclusion criteria for the RSA and TSA cohorts.

TABLE I Demographic Information

	TSA Group (N = 67)	RSA Group (N = 67)	P Value
Duration of clinical follow-up* *(mo)*	32.8 ± 13.4	27.2 ± 6.0	<0.001†
Age* *(yr)*	67 ± 4.7	67 ± 3.5	0.98
Female sex *(no. of patients)*	39 (58.2%)	41 (61.2%)	0.73
BMI* *(kg/m²)*	30.6 ± 6.6	32.5 ± 6.9	0.12
ASA physical status score* ǂ	2.1 ± 0.5	2.2 ± 0.5	0.55
Prior ipsilateral shoulder surgery *(no. of patients)*	7 (10.4%)	11 (16.4%)	0.45
Walch classification *(no. of patients)*			
A1	25 (37.3%)	17 (25.4%)	0.14
A2	1 (1.5%)	7 (10.4%)	0.06
B1	3 (4.5%)	4 (6.0%)	0.99
B2	24 (35.8%)	19 (28.4%)	0.32
B3	10 (14.9%)	15 (22.4%)	0.27
C	3 (4.5%)	3 (4.5%)	0.99
D	1 (1.5%)	2 (3%)	0.99

*The values are expressed as the mean and the standard deviation. †Significant. ǂASA = American Society of Anesthesiologists.

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The present study received no external funding.

Results

The initial query identified 849 patients who had undergone TSA (263) or RSA (586). After application of inclusion and exclusion criteria, 147 patients (56%) who had undergone TSA and 173 patients (30%) who had undergone RSA were eligible to be propensity score-matched by age, sex, BMI, preoperative ASES score, preoperative active forward elevation, and Walch classification in a 1:1 fashion. The final matched cohort included 134 patients (67 patients in each group) with a mean duration of follow-up of 30 ± 10.7 months (Fig. 1). There were no significant differences in mean age ($p = 0.98$), sex ($p = 0.73$), BMI ($p = 0.12$), Walch classification ($p > 0.05$), or prior surgery (all of which were debridements) ($p = 0.45$) (Table I). The average duration of follow-up was greater for the TSA group (32.8 ± 13.4 months) than for the RSA group (27.2 ± 6 months) ($p < 0.001$).

No significant differences were found between the TSA and RSA groups in terms of the baseline or final VAS pain scores ($p = 0.99$ and $p = 0.99$, respectively), ASES scores ($p = 0.99$ and $p = 0.49$, respectively), or SANE scores ($p = 0.22$ and $p = 0.73$, respectively). In addition, baseline-to-postoperative changes in PROMs did not significantly differ between groups (VAS pain, $p = 0.86$; SANE, $p = 0.08$; ASES, $p = 0.17$) (Fig. 2). The MCID for the ASES was achieved by 65 patients (97%) in the RSA group and 67 patients (100%) in the TSA group ($p = 0.50$). The SCB for the ASES was achieved by 62 patients (92.5%) in the RSA group and by 64 patients (95.5%) in the TSA group ($p = 0.72$) (Table II).

Patients who had undergone TSA demonstrated significantly better postoperative active forward elevation (149° ± 13° versus 142° ± 15°; $p = 0.003$), external rotation (63° ± 14° versus 57° ± 18°; $p = 0.02$), and internal rotation to ≥L3 (68.7% versus 37.3%; $p < 0.001$); however, there were only significant baseline-to-postoperative improvements in internal rotation (gain of ≥4 levels in 53.7% versus 31.3%; $p = 0.009$) (Table II).

Complications occurred in 6 (4.5%) of the 134 patients (3 patients in each group, $p = 0.99$). In the TSA group, 1 patient sustained a postoperative rotator cuff tear and underwent revision to RSA, 1 patient sustained a transient ulnar nerve palsy, and 1 patient developed a postoperative hematoma. In the RSA group, 1 patient sustained a transient radial nerve palsy, 1 patient sustained an intraoperative glenoid fracture, and 1 patient sustained a traumatic postoperative acromial stress fracture that was successfully treated nonoperatively. The duration of radiographic follow-up was not significantly different between TSA (mean, 30.9 months) and RSA (28.7 months) ($p = 0.11$). Ten patients (14.9%) in the TSA group had radiolucent lines in at least 1 zone around the glenoid component. No patient had gross glenoid component loosening. No glenoid component loosening occurred in the RSA group. The revision rate was 1.5% (1 of 67) in the TSA group, compared with 0% in the RSA group.

Discussion

The present study demonstrated similar short-term PROMs following TSA and RSA in the setting of osteoarthritis in patients with an intact rotator cuff. The TSA group significantly better postoperative active range of motion as compared with the RSA group. Differences in range of motion must be balanced against clinical outcomes and long-term risk of revision surgery when deciding the most appropriate arthroplasty option for patients with primary osteoarthritis.

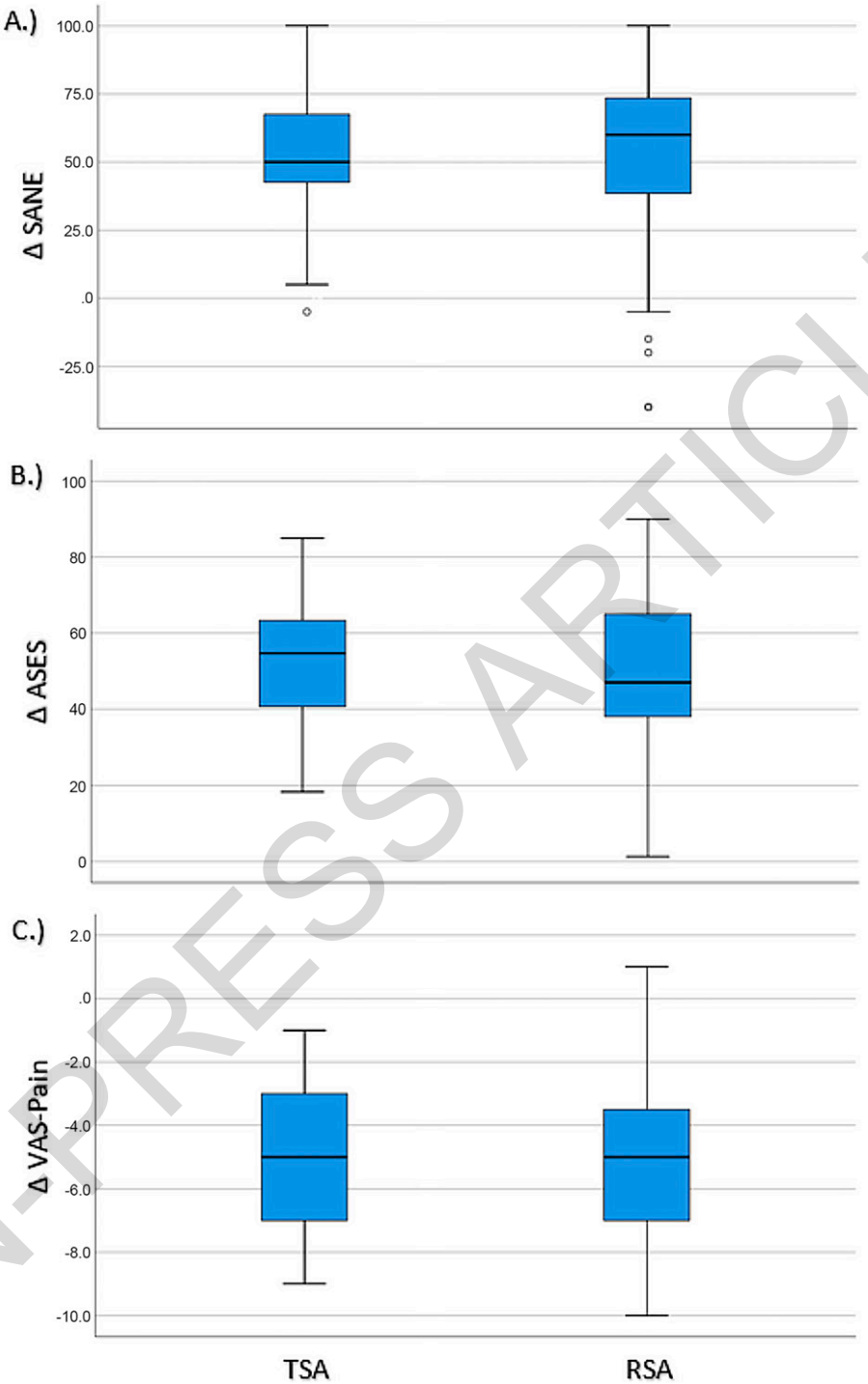

Fig. 2

Figs. 2-A, 2-B, and 2-C Box plots of preoperative to postoperative changes in patient-reported outcomes for TSA and RSA. **Fig. 2-A** Change in SANE scores. **Fig. 2-B** Change in ASES scores. **Fig. 2-C** Change in VAS pain scores.

The increased volume of shoulder arthroplasty over recent years has largely been driven by expanding indications for, and increased utilization of, RSA[1-3]. RSA accounted for only 33% of all shoulder arthroplasties in the United States as of 2011[24]; however, as of 2017, RSA accounted for approximately 60% of all shoulder arthroplasty volume[1]. Over a similar time frame, the number of surgeons performing shoulder arthroplasty has increased sixfold[18]. The indications for RSA also have

TABLE II Clinical Outcomes*

Outcome	TSA Group (N = 67)	RSA Group (N = 67)	P Value
VAS pain score†			
Preop.	6 (3)	5 (4)	0.99
Postop.	0 (0)	0 (0)	0.99
Change	−5 (4)	−5 (4)	0.86
SANE score†			
Preop.	40 (25)	30 (30)	0.22
Postop.	95 (10)	95 (10)	0.73
Change	50 (30)	60 (37)	0.08
ASES score			
Preop.†	38.3 (22)	38 (27)	0.99
Postop.†	95 (11.7)	93.3 (13.3)	0.49
Change†	54.7 (23.3)	47 (27)	0.17
Achieved MCID *(no. of patients)*	67 (100%)	65 (97%)	0.50
Achieved SCB *(no. of patients)*	64 (95.5%)	62 (92.5%)	0.72
Forward elevation‡ *(deg)*			
Preop.	98.1 ± 25	99.4 ± 26	0.77
Postop.	148.9 ± 13	141.7 ± 15	0.003§
Change	50.8 ± 27	42 ± 28	0.08
External rotation‡ *(deg)*			
Preop.	29.1 ± 10	25 ± 13	0.04§
Postop.	63 ± 14	56.9 ± 18	0.02§
Change	34.2 ± 13	31.9 ± 20	0.43
Internal rotation *(no. of patients)*			
Preop.			0.89
Hip-L4	60 (89.6%)	63 (94%)	
L3-T12	7 (10.4%)	4 (6%)	
Postop.			
Hip-L4	21 (31.3%)	42 (62.7%)	<0.001§
L3-T12	44 (65.7%)	22 (32.8%)	<0.001§
T11-T9	2 (3%)	3 (4.5%)	0.99
Change			
Loss or no change	11 (16.4%)	12 (17.9%)	0.82
Gain of 1-3 levels	20 (29.9%)	34 (50.7%)	0.01†
Gain of 4-6 levels	28 (41.8%)	17 (25.4%)	0.04†
Gain of ≥7 levels	8 (11.9%)	4 (6%)	0.22

*ASES = American Shoulder and Elbow Surgeons, VAS = visual analog scale, SANE = Single Assessment Numeric Evaluation. †The values are expressed as the median, with the width of the interquartile range in parentheses. ‡The values are expressed as the mean and the standard deviation. §Significant.

evolved, with recent evidence suggesting that 33% of all RSAs are performed for osteoarthritis, which represents the largest increase in incidence by preoperative diagnosis[1].

Increased utilization of RSA for the treatment of osteoarthritis in patients with an intact rotator cuff may be secondary to concerns about anatomic glenoid component loosening and rotator cuff dysfunction after TSA, coupled with favorable clinical outcomes and decreased revision rates following RSA[14-18]. Glenoid component loosing and secondary rotator cuff failure increase substantially at 10 to 15 years following TSA[14,15]. Evans et al.[14] recently reported glenoid loosing and secondary rotator cuff failure in approximately 75% of patients at 15 years of follow-up. This rate of glenoid loosening is similar to what was reported by McLendon et al. at 10 years of follow-up[15]. Anatomic glenoid loosening has been associated with decreased patient-reported outcome scores[25] as well as high rates of reoperation and baseplate failure following revision surgery[26]. Our overall complication rate of 4.5% and

revision rate of 0.75% were low; however, these rates are comparable with the findings of Parada et al.[17], who reported short-term complication rates of 10.7% and 8.9% and revision rates of 5.6% and 2.5% after TSA and RSA, respectively. Large registry studies have demonstrated lower rates of revision surgery in association with RSA as compared with TSA after both short-term[17] and long-term[18] follow-up. Brown et al. reported that the overall cumulative revision rate at 9 years was approximately 12% for TSA as compared with 6% to 7% for RSA in the setting of osteoarthritis[18]. Collin et al.[27] reported excellent clinical outcomes, no evidence of component loosening, and a 94% survival rate at 10 years of follow-up after RSA for osteoarthritis in patients with advanced glenoid deformity[27]. These data may be influenced by the difference that treating surgeons perceive between suitable options for revision arthroplasty after TSA and after RSA.

In the present study, we found no significant differences between the RSA and TSA groups in terms of complication rates or PROMs. One patient in the TSA group required revision to RSA for a rotator cuff tear. These findings are consistent with the recent literature[8,9,13]; however, higher rates of glenoid loosening and revision have been reported in association with TSA as compared with RSA[8,9].

Our study demonstrated significantly better postoperative range of motion in association with TSA as compared with RSA. These differences, while statistically significant, have questionable clinical importance. Greater internal rotation is usually encountered after TSA than after RSA; however, other differences have been inconsistently demonstrated[8,9,13]. Simovitch et al.[23] previously reported that even modest improvements in range of motion can result in clinically meaningful differences for patients after shoulder arthroplasty. The difference in postoperative motion is important to consider in the context of overall revision rates and other clinically meaningful patient-reported outcomes when counseling patients considering either TSA or RSA in the setting of osteoarthritis.

The present study has several limitations. The data reflect a single surgeon's experience and therefore may not be generalizable. Inherent to this limitation was the evolving indications in the senior surgeon's practice toward the more frequent use of RSA in the setting of primary osteoarthritis irrespective of glenoid morphology. This trend toward RSA for primary osteoarthritis may have resulted in confirmation bias. We utilized propensity score matching of age, BMI, sex, preoperative ASES score, preoperative active forward elevation, and Walch glenoid morphology to minimize the risk of bias. There was also variability in the use of different anatomic humeral implants. While this variability adds some heterogeneity, there is currently no evidence to suggest that the use of different anatomic humeral implants influences clinical outcomes. Additionally, all clinical outcome data were prospectively collected; however, the retrospective study design and analysis may introduce biases as well. Reviewers determining glenoid morphology were blinded from clinical outcome data to limit bias. Another limitation was the short-term follow-up. Longer follow-up is needed to determine the ultimate value of RSA as compared with TSA in the setting of osteoarthritis as complications leading to revision surgery are more likely to occur with time.

We present a large consecutive series of patients undergoing TSA and RSA for primary osteoarthritis with a high rate of follow-up as well as propensity score matching by age, BMI, sex, preoperative ASES score, preoperative active forward elevation, and glenoid morphology. This is the only study, to our knowledge, in which the patient groups were matched by glenoid morphology and contained a substantial proportion of shoulders with less-severe glenoid pathology. Similar studies have had a large bias toward including patients with mostly more-advanced glenoid pathology (i.e., Walch type-B2, B3, and C glenoids)[8,9,13,27]. We believe that this study presents a more balanced perspective regarding the role of RSA in osteoarthritis (not just in more severe pathology) and how it compares to TSA. All clinical outcomes were prospectively collected and maintained in an institutional database, thereby minimizing recall bias.

Conclusions

TSA and RSA resulted in similar short-term PROMs in the setting of primary osteoarthritis in patients with an intact rotator cuff. Postoperative active range of motion was better after TSA; however, the differences were of questionable clinical importance. Longer follow-up is needed to determine the ultimate value of RSA in the setting of osteoarthritis in patients with an intact rotator cuff. ■

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