Anatomic Versus Reverse Total Shoulder Arthroplasty for Primary Osteoarthritis with an Intact Rotator Cuff: A Mid-term Comparison of Early Top Performers

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Abstract

Background: Many surgeons state that their best anatomic total shoulder arthroplasty (aTSA) outperforms their best reverse total shoulder arthroplasty (rTSA) when performed for rotator cuff-intact glenohumeral osteoarthritis (RCI-GHOA). We identified the top performing aTSAs and rTSAs at short-term follow-up and compared their clinical performance at mid-term follow-up to validate this common claim.

Methods: A retrospective review of a multicenter shoulder arthroplasty database was performed. All shoulders undergoing primary aTSA or rTSA for RCI-GHOA between 2007-2020 were reviewed. Shoulders with a follow-up clinical visit between 2-3 years and clinical follow-up of minimum 5 years were included. Two separate cohorts were identified: patients with a top 20% (1) American Shoulder and Elbow Surgeons (ASES) score and (2) Shoulder Arthroplasty Smart (SAS) score at 2-3-year follow-up. Clinical outcomes including range of motion, outcome scores, and rates of complications and reoperations were compared at minimum 5-year follow-up.

Results: Active external rotation was greater after aTSA at mid-term follow-up in both ASES and SAS score cohorts; however, pre- to postoperative improvement was equivalent. Postoperative external rotation and SAS score was greater after aTSA in both cohort ($P<0.05$); however, no other significant differences in any preoperative or postoperative clinical outcomes were present

(*P*>0.05) and patients achieved the MCID and SCB at similar rates for all outcomes. No difference in the incidence of complications and reoperation was found between top performing aTSAs and rTSAs.

Conclusion: Among top performing shoulder arthroplasties at early follow-up, aTSA does not appear to outperform rTSA with the exception of superior ER at mid-term follow-up.

Level of Evidence: Retrospective comparative cohort study, Level III

Keywords: shoulder replacement; rotator cuff; cuff intact; arthritis; patient-reported outcome

INTRODUCTION

The optimal management of rotator cuff-intact glenohumeral osteoarthritis (RCI-GHOA) in patients who have exhausted nonoperative management is often debated.[1–5] Many surgeons state that their best anatomic total shoulder arthroplasty (aTSA) outperforms their best reverse total shoulder arthroplasty (rTSA). Recent studies have demonstrated similar outcomes between aTSA and rTSA performed for RCI-GHOA; however aTSAs typically have greater motion, particularly in rotation.[3,4,6] Additionally, Swanson et al.[7] recently compared the 2-year minimum clinical outcomes (average 33±14 months) in 40 aTSAs and 88 rTSAs with top 20% ASES scores and found superior external and internal rotation after aTSA, but equivalent outcomes otherwise. However, only short-term outcomes were assessed and 100% of included aTSAs and 73% of rTSAs had RCI-GHOA; rTSAs with rotator cuff arthropathy (n=19) or rotator cuff tear (n=2) were also included. Given reported rates of radiographic glenoid loosening as high as 57% at 10 years and rotator cuff dysfunction as high as 55% at 15 years after aTSA,[8–10] previously reported similarities in clinical outcomes seen at short-term follow-up may not persist with longer follow-up.

The purpose of this study is to identify the top performing aTSAs and rTSAs performed for RCI-GHOA from a multicenter database using a single implant design at 2-year follow-up and compare their clinical and radiographic outcomes at minimum 5-year follow-up. We hypothesized that there would be no difference in clinical outcomes at minimum 5-year follow-up between aTSAs and rTSAs that were top performers at 2-3-year follow-up.

MATERIALS AND METHODS

A retrospective review of a multicenter international shoulder arthroplasty database was performed between 2007 and 2020. We identified patients with RCI-GHOA undergoing aTSA or rTSA with a minimum of two clinical follow-up visits: (1) between 2-3 years and (2) at minimum 5 years. We included the follow-up visit closest to 5-year follow-up in patients with multiple follow-up visits to ensure an equitable comparison. Shoulders with postoperative infection, nerve injury, or periprosthetic fracture were excluded because prior reports have demonstrated poorer clinical performance in these populations.[11–13] A single platform shoulder arthroplasty system was used for all procedures (Equinoxe; Exactech, Inc., Gainesville, FL, USA). This system comprises a medialized glenoid, lateralized humerus design with a 145° neck-shaft angle.[14] Shoulder arthroplasties were performed by one of 36 shoulder surgeons.

Clinical Outcomes

Range of motion (ROM) and clinical outcome scores were evaluated at preoperative and postoperative visits. Active ROM measures assessed included abduction, forward elevation (FE), external rotation (ER), and internal rotation (IR) and were standardized across study sites. IR was assessed as the most cephalad vertebral level reached by the thumb behind the patient's back and scored as follows: no IR, 0; hip, 1; buttocks, 2; sacrum, 3; L5 to L4, 4; L3 to L1, 5; T12 to T8, 6; and T7 or higher, 7.[15] Clinical outcome scores evaluated included the Simple Shoulder Test (SST), the Constant score, the ASES score, the University of California, Los Angeles (UCLA) score, the Shoulder Pain and Disability Index (SPADI), and the Shoulder Arthroplasty Smart (SAS) score.[16] In addition, the incidence of complications and revision surgery was evaluated.

Study Cohorts

Given the known presence of ceiling effects in commonly utilized shoulder outcome scores, we identified two patient cohorts comprised of aTSAs and rTSAs that achieved a top 20% outcome at 2-3-year follow-up. The first cohort was created based on the ASES score given its ubiquity and prior validation.[17] The second cohort was created based on the SAS score,[16] which has been demonstrated to correlate strongly with legacy shoulder scores, including the ASES score, while avoiding ceiling effects,[18] which obscure subtle but clinically-important differences in patient outcomes due to aggregation near the maximum value (i.e., left-skew).[19]

Handling of Missing Data

The rate of missing data was 16-20% for ROM, 1.3% for the ASES score, and 20% for the SAS score. We utilized multivariate random forest imputation to reduce the influence of missing clinical outcome data and therefore reduce potential for selection bias.[20] This method has been used previously in the shoulder surgery literature.[21,22] First, missing values are imputed with a rough estimate; subsequently, a predictive random forest is trained and used to re-impute missing values in an iterative manner until convergence. Single imputation was performed using the *simputation* package.[23]

Statistical Analysis

Our primary outcomes were ROM and outcome scores compared between prostheses. Two-sided unpaired Welch's t-tests were used to compare continuous measures. Fisher's Exact test was used to compare categorical measures. Additionally, clinical significance was further evaluated by comparing the proportion of patients with improvement exceeding the minimal clinically

important difference (MCID) and substantial clinical benefit (SCB) derived for primary aTSA from prior reports utilizing the same prosthesis.[16,24,25] *P* values for clinical outcome comparisons were additionally adjusted for multiple comparisons using the Benjamini and Hochberg false discovery rate. The incidence of complications and reoperation after early 2–3-year follow-up was compared between top performing aTSAs and rTSAs and to the comparison cohort of bottom 80% aTSAs and rTSAs based on the ASES and SAS score. All statistical analyses were performed using R Software (version 4.2.0, R Core Team, Vienna, Austria) with a defined $\alpha = 0.05$.

RESULTS

Patients

We initially identified 880 shoulder arthroplasties (673 aTSA, 207 rTSA) performed for RCI-GHOA that met clinical follow-up criteria. The top 20% ASES score was 100 for aTSA and 98 for rTSA. The top 20% SAS score was 90.5 for aTSA and 85.9 for rTSA. Applying these criteria, we included 185 aTSAs and 49 rTSAs in the top 20% ASES cohort and 145 aTSAs and 42 rTSAs in the top 20% SAS cohort. In both cohorts, patients that underwent aTSA were on average younger ($P \leq .001$), but had similar BMI and proportion of females compared to rTSAs (**Table I)**.

Top 20% ASES score cohort

After adjusting for multiple comparisons, there were no statistically significant differences in preoperative range of motion and outcome scores (**Table II**). Postoperatively, aTSAs had greater active ER (57±14° vs. 46±17°, $P=.001$) and SAS score (86.0±6.4 vs. 82.8±6.9, $P=.021$). However, pre- to postoperative improvement in all clinical outcomes was similar between prostheses and no differences in the proportion of patients achieving the MCID nor the SCB were found (**Table III**). Two complications occurred after 2-3-year follow-up after aTSA (**Table IV**), including one rotator cuff tear treated nonoperatively and one case of aseptic loosening of the glenoid component which required revision surgery. No complications or reoperations occurred in the rTSA cohort. Neither complication nor revision rates differed between top performing aTSAs and rTSAs ($P=1.000$ for both). The complication and reoperation rates during midterm follow-up were lower in aTSAs with top 20% ASES scores versus bottom 80% ASES scores at early follow-up (1.1% vs. 5.3%, $P=.015$ and 0.5% vs. 3.5%, $P=.033$), but no difference was found between top 20% and bottom 80% rTSAs.

Top 20% SAS score cohort

Preoperative ER was greater in the aTSA cohort after adjusting for multiple comparisons (29±20° vs. 19±18°, *P*=.046); no other differences were present preoperatively (**Table II**). Postoperatively, aTSAs had greater active ER (62±13° vs. 49±19°, *P*=.001) and SAS score (88.3±5.1 vs. 84.9±5.5, *P*=.003). However, pre- to postoperative improvement in all clinical outcomes was similar between prostheses and no differences in the proportion of patients achieving the MCID nor the SCB were found (**Table III**). One complication occurred after 2-3-year follow-up after aTSA (**Table IV**), consisting of a rotator cuff tear treated nonoperatively. No complications or reoperations occurred in the rTSA cohort. Neither complication nor revision rates differed between top performing aTSAs and rTSAs (*P*=1.000 for both). The complication rate during midterm follow-up was lower in aTSAs with top 20% SAS scores versus bottom 80% SAS scores at early follow-up (0.7% vs. 5.0%, *P*=.017), but no difference was found between top 20% and bottom 80% rTSAs.

DISCUSSION

The use of aTSA versus rTSA for the treatment of RCI-GHOA remains debated.[3–5,26] Many surgeons claim their best aTSA outperforms their best rTSA, but little evidence is available to substantiate these claims particularly when patients are evaluated past initial 2-year follow-up. When evaluating the top 20% of aTSAs and rTSAs based on ASES and SAS scores at early follow-up, we found that the majority of clinical outcomes assessed at mid-term (5-year) follow-up were comparable between cohorts. However, aTSAs demonstrated superior ER and statistically better SAS scores compared to rTSAs with similar rates of complications and reoperations. These findings demonstrate that both aTSA and rTSA can provide excellent clinical outcomes in patients with RCI-GHOA.

The similarity in the durability of clinical outcomes of both aTSA and rTSA evaluated at mid-term follow-up challenges the assertions made by many surgeons regarding the superiority of the function attained by their top performing aTSA patients. Although the top performing aTSA cohort demonstrated superior ER and SAS scores, these differences did not exceed the MCID or SCB in our study (**Table III**). Swanson et al.[7] previously evaluated 40 aTSAs and 88 rTSAs with top 20% ASES scores at a mean follow-up of 33±14 months and found similar outcomes between cohorts. Our study builds upon their study by evaluating early top performing TSAs at mid-term follow-up, limiting inclusion to patients with a preoperative diagnosis of RCI-GHOA, and utilizing a single implant design. Furthermore, we identified the top 20% of patients using both the ASES and SAS scores. In comparison to the ASES score, the SAS score provides a functional evaluation of patients without suffering from the ceiling effect.[16] The ceiling effect, defined as the aggregation of scores near the maximal value (i.e., left skew), limits our ability to use statistics to identify small

but clinically significant differences among top performers. Similarly to a prior study by Marigi et al.[3] that only identified a difference between aTSAs and rTSAs performed for RCI-GHOA when compared using the SAS score, our study found superior SAS scores in aTSAs versus rTSAs at mid-term follow-up after adjusting for multiple comparisons when the early cohort of top performers was conceived according to the SAS score, but not the ASES score (**Table II**). Given that range of motion is included in the calculation of the SAS score, our findings demonstrate that top performing aTSAs have statistically superior ER at mid-term follow-up, but this difference may not be relevant to patient satisfaction or quality of life.

We noted a higher incidence of complications and reoperations that occurred between early and mid-term follow-up after aTSA, whereas no complications or reoperations occurred in the rTSA cohorts (**Table II**). While not statistically significant, these findings highlight some surgeons' concerns regarding the durability of aTSA outcomes even in initial top performers. Prior studies have demonstrated a high incidence of radiographic glenoid lucencies at mid-term follow-up, with lucency rates as high as 60% being described and more than one-third of these have been shown to be radiographically loose.[9,27,28] Schoch et al.[29] showed that these lucencies found in many aTSAs at mid-term also may have significant effects on ROM and patient-reported outcome. Longer follow-up is needed to establish the clinical significance of these findings. While glenoid component loosening is not a major concern after rTSA, previous literature has demonstrated that rTSAs may experience deleterious outcomes at mid-term follow-up from deltoid fatigue, whereby the non-physiological biomechanical requirements of rTSA lead to impaired deltoid efficiency and senescence, and ultimately worsening function.[30,31] Bacle et al.[30] in their study of 191 rTSAs at a mean follow-up of 40 months, found a decrease in the relative Constant score and forward

elevation between mid- and long-term follow-up. However, similar to Schoch et al.[32] who challenged the previous theory of deltoid fatigue by noting minimal loss of overhead ROM during a 5-year period (0.8° per year) that progressed at a similar rate as the natural aging shoulder, rTSAs in this cohort demonstrated excellent overhead motion at mid-term follow-up. Future long-term follow-up studies evaluating aTSAs and rTSAs at minimum 10 years are needed to substantiate the durability of the outcomes we report at mid-term follow-up.

While aTSA demonstrated superior postoperative ER, we found improvement in rotation to be equivalent between aTSAs and rTSAs, including achieving the MCID and SCB at similar rates for rotational motion (**Table III**). Notably, in both the ASES and SAS score cohorts, aTSAs started with greater ER preoperatively. Hence, the top performing rTSAs may not be inherently predisposed to poorer axial ROM. This may be related to improvements in modern rTSA implants such as the one utilized in the current study, which tensions the posterior rotator cuff and deltoid, improve deltoid wrap, and improve the deltoid moment arm.[33–36] In fact, Berglund et al.[37] evaluated 33 rTSAs with preoperative ER deficits (<0°) at an average follow-up of 43.4 months and reported significant improvement in ER after rTSA using a lateralized design and without tendon transfer augmentation in patients with combined loss of elevation and ER (CLEER) (-21° preoperatively to 28° postoperatively; $P<0.001$) and patients without CLEER (-19° preoperatively to 26° postoperatively; $P<0.001$). Furthermore, IR score was similar between top performng aTSAs and rTSAs. Future studies that assess whether the quality of the rotator cuff on advanced imaging is prognostic of patient outcomes after aTSA versus rTSA for RCI-GHOA are needed.

This study has several limitations. While patents were followed prospectively, the retrospective nature of the study limits its conclusions. The use of a single implant design may limit the generalizability of this study. The inclusion of patients from 36 surgeons at various clinical sites provides more generalizable findings, but introduces variability in practices and protocols. Shoulder range of motion at follow-up visits was recorded by different clinical research assistants; however, measurements were performed using standardized techniques. The decision to perform an aTSA or rTSA was left to surgeon discretion and is dependent on many factors, such as surgeon preference, glenoid deformity, and patient demographics and functional demands, which could not be controlled for.

CONCLUSION

Among top performing shoulder arthroplasties at early (2-3 year) follow-up, aTSAs and rTSAs performed for RCI-GHOA demonstrated similar range of motion and outcome scores at mid-term (5-year) follow-up. aTSAs had superior postoperative ER, but improvement from preoperative status was similar to rTSAs and differences between cohorts were not clinically relevant. The incidence of complications and reoperation during midterm follow-up was similar between top performing aTSAs and rTSAs. Future studies are needed to evaluate the durability of these outcomes at long-term follow-up.

FIGURE LEGENDS

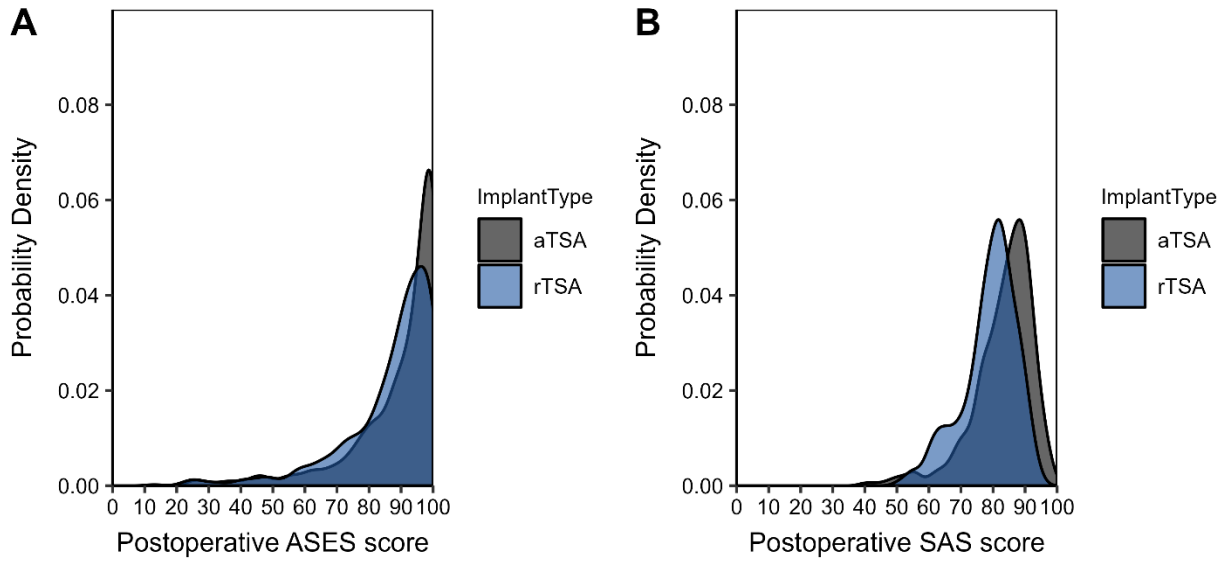

Figure 1. Distribution of postoperative ASES (A) and SAS scores (B) at 2–3-year follow-up after aTSA or rTSA in the full patient cohort (n=880) demonstrating a ceiling effect for the ASES score, but not the SAS score. ASES, American Shoulder and Elbow Surgeons; aTSA, anatomic total shoulder arthroplasty; rTSA, reverse total shoulder arthroplasty; SAS, Shoulder Arthroplasty Smart.

Table I: Characteristics of included aTSA and rTSA with top 20% ASES and SAS scores at 2- or 3-year follow-up.

Variable	Top 20% ASES			Top 20% SAS		
	aTSA (n=185)	rTSA (n=49)	*P*	aTSA (n=145)	rTSA (n=42)	*P*
Age at surgery (years)	66.8 ± 7.1	71.5 ± 7.7	**<.001**	66.9 ± 7.1	71.2 ± 6.9	**.00**
BMI (kg/m^2)	28.8 ± 5.3	28.1 ± 4.7	.341	28.4 ± 5.9	28.1 ± 6.1	.81
Follow-up (months)	66.1 ± 8.5	64.6 ± 8.1	.271	64.9 ± 9.4	66.4 ± 8.0	.28
Female sex	41.6% (77)	44.9% (22)	.746	59.3% (86)	57.1% (24)	.85
Dominant side surgery	56.0% (103)	57.1% (28)	1.000	52.4% (76)	59.5% (25)	.48
Comorbidities						
Hypertension	47.4% (81)	32.7% (16)	.074	50.7% (72)	33.3% (14)	.05
Heart disease	11.1% (19)	4.1% (2)	.175	6.3% (9)	2.4% (1)	.45
Diabetes	5.8% (10)	16.3% (8)	**.033**	7.7% (11)	7.1% (3)	1.0
Tobacco use	8.2% (14)	6.1% (3)	.769	7.0% (10)	2.4% (1)	.46
Received shoulder injections	40.4% (74)	27.1% (13)	.097	50.3% (73)	31.0% (13)	**.03**
Cemented humeral component	24.9% (46)	6.1% (3)	**.003**	20.7% (30)	4.8% (2)	**.01**
Previous surgery on shoulder	15.1% (28)	14.6% (7)	1.000	15.2% (22)	14.3% (6)	1.0

BMI, body mass index; IQR, interquartile range; rTSA, reverse total shoulder arthroplasty.
P values were computed using two-sided unpaired Welch's t-tests and Fisher's exact tests, where appropriate.
Bold values indicate statistical significance.

Table II. Comparison of mid-term (5-year) clinical outcomes between aTSA versus rTSA with top 20% ASES and SAS scores* at 2- or 3-year follow-up.

Outcome measure	Top 20% ASES				Top 20% SAS			
	aTSA (n=185)	rTSA (n=49)	*P*	*Adj. P**	aTSA (n=145)	rTSA (n=42)	*P*	*Adj. P**
Preoperative								
Active abduction (°)	88 ± 29	83 ± 27	.221	.442	94 ± 29	83 ± 32	.053	.265
Active FE (°)	104 ± 30	98 ± 24	.157	.393	110 ± 30	103 ± 32	.194	.646
Active IR score	3.4 ± 1.4	3.0 ± 1.7	.109	.362	3.8 ± 1.3	3.6 ± 2.0	.450	.687
Active ER (°)	25 ± 20	18 ± 19	**.019**	.187	29 ± 20	20 ± 18	**.007**	.070
SST score	5.4 ± 3.1	5.0 ± 2.8	.322	.536	5.4 ± 3.0	5.1 ± 3.0	.621	.690
Constant score	41.7 ± 12.8	41.2 ± 11.9	.804	.899	43.4 ± 13.6	43.2 ± 13.9	.938	.938
ASES score	42.1 ± 16.7	41.5 ± 16.9	.809	.899	40.9 ± 15.6	44.1 ± 17.8	.304	.687
UCLA score	15.3 ± 4.1	15.3 ± 3.7	.949	.949	15.6 ± 4.2	16.1 ± 3.9	.534	.687
SPADI score	74.0 ± 25.3	75.5 ± 21.6	.683	.899	74.6 ± 23.5	72.2 ± 22.8	.550	.687
SAS score	50.6 ± 10.1	47.7 ± 11.0	.101	.362	52.0 ± 10.4	50.8 ± 11.5	.543	.687
Postoperative								
Active abduction (°)	141 ± 25	132 ± 26	.055	.182	146 ± 26	141 ± 25	.243	.304
Active FE (°)	154 ± 19	153 ± 16	.707	.707	160 ± 20	158 ± 12	.385	.427
Active IR score	5.4 ± 0.9	5.1 ± 1.3	.091	.182	5.7 ± 0.9	5.5 ± 0.9	.222	.304
Active ER (°)	57 ± 14	46 ± 17	**<.001**	**.001**	62 ± 13	49 ± 19	**<.001**	**.001**
SST score	11.5 ± 1.0	11.1 ± 1.5	.080	.182	11.6 ± 0.7	11.1 ± 1.2	**.019**	.055
Constant score	78.9 ± 8.6	77.7 ± 7.7	.357	.397	80.2 ± 8.1	80.2 ± 6.8	.966	.966
ASES score	95.3 ± 9.6	92.6 ± 12.2	.167	.239	95.2 ± 7.6	92.3 ± 10.4	.102	.204
UCLA score	33.2 ± 2.3	32.8 ± 2.3	.292	.364	33.5 ± 1.9	33.1 ± 1.8	.175	.292
SPADI score	5.8 ± 10.6	9.4 ± 16.4	.150	.239	4.8 ± 7.9	9.1 ± 11.0	**.022**	.055
SAS score	86.0 ± 6.4	82.8 ± 6.9	**.004**	**.021**	88.3 ± 5.1	84.9 ± 5.5	**.001**	**.003**
Improvement								
Active abduction (°)	53 ± 32	49 ± 32	.413	.793	52 ± 34	58 ± 37	.381	.635
Active FE (°)	52 ± 29	55 ± 29	.573	.793	51 ± 31	55 ± 33	.476	.680
Active IR score	2.1 ± 1.4	2.1 ± 1.6	.854	.945	2.0 ± 1.2	1.9 ± 1.7	.972	.977
Active ER (°)	33 ± 21	27 ± 20	.100	.793	34 ± 21	29 ± 21	.224	.542
SST score	6.3 ± 3.1	6.3 ± 2.6	.945	.945	6.3 ± 3.0	6.1 ± 2.9	.750	.937
Constant score	37.3 ± 13.0	36.0 ± 12.3	.524	.793	36.5 ± 14.1	36.4 ± 14.0	.977	.977
ASES score	53.2 ± 19.0	51.2 ± 19.3	.505	.793	54.5 ± 17.4	48.2 ± 19.1	.060	.542
UCLA score	17.8 ± 4.4	17.4 ± 4.4	.559	.793	17.9 ± 4.2	17.0 ± 4.5	.259	.542
SPADI score	-68.7 ± 25.6	-66.8 ± 24.0	.634	.793	-69.7 ± 24.6	-65.2 ± 22.6	.269	.542
SAS score	35.9 ± 11.4	34.5 ± 11.9	.465	.793	36.2 ± 11.3	33.8 ± 12.7	.271	.542
Complications	0.5% (1)	0.0% (0)	1.000	-	0.0% (0)	0.0% (0)	1.000	-
Required revision surgery	0.5% (1)	0.0% (0)	1.000	-	0.0% (0)	0.0% (0)	1.000	-

ASES, American shoulder and elbow surgeons; aTSA, anatomic total shoulder arthroplasty; ER, external rotation; FE, forward elevation; IR, internal rotation; rTSA, reverse total shoulder arthroplasty; SAS, shoulder arthroplasty smart; SPADI, shoulder pain and disability index; Subscapularis, subscapularis; SST, simple shoulder test.
Values represent mean ± standard deviation unless otherwise noted. Bold indicates statistical significance.
*P values for clinical outcomes were adjusted for multiple comparisons using the Benjamini and Hochberg false discovery rate.

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Active ER (°)	33 ± 21	27 ± 20	.100	.793	34 ± 21	29 ± 21	.224
SST score	6.3 ± 3.1	6.3 ± 2.6	.945	.945	6.3 ± 3.0	6.1 ± 2.9	.750
Constant score	37.3 ± 13.0	36.0 ± 12.3	.524	.793	36.5 ± 14.1	36.4 ± 14.0	.977
ASES score	53.2 ± 19.0	51.2 ± 19.3	.505	.793	54.5 ± 17.4	48.2 ± 19.1	.060
UCLA score	17.8 ± 4.4	17.4 ± 4.4	.559	.793	17.9 ± 4.2	17.0 ± 4.5	.259
SPADI score	-68.7 ± 25.6	-66.8 ± 24.0	.634	.793	-69.7 ± 24.6	-65.2 ± 22.6	.269
SAS score	35.9 ± 11.4	34.5 ± 11.9	.465	.793	36.2 ± 11.3	33.8 ± 12.7	.271
Complications	0.5% (1)	0.0% (0)	1.000	-	0.0% (0)	0.0% (0)	1.000
Required revision surgery	0.5% (1)	0.0% (0)	1.000	-	0.0% (0)	0.0% (0)	1.000

ASES, American shoulder and elbow surgeons; aTSA, anatomic total shoulder arthroplasty; ER, external rotat FE, forward elevation; IR, internal rotation; rTSA, reverse total shoulder arthroplasty; SAS, shoulder arthropla smart; SPADI, shoulder pain and disability index; Subscapularis, subscapularis; SST, simple shoulder test. Values represent mean ± standard deviation unless otherwise noted. Bold indicates statistical significance.

*P values for clinical outcomes were adjusted for multiple comparisons using the Benjamini and Hochberg fal
discovery rate.

Table II. Comparison of mid-term (5-year) clinical outcomes between aTSA versus rTSA with top 20% ASES SAS scores* at 2- or 3-year follow-up.

Outcome measure	Top 20% ASES				Top 20% SAS		
	aTSA (n=185)	rTSA (n=49)	*P*	*Adj. P**	aTSA (n=145)	rTSA (n=42)	*P*
Preoperative							
Active abduction (°)	88 ± 29	83 ± 27	.221	.442	94 ± 29	83 ± 32	.053
Active FE (°)	104 ± 30	98 ± 24	.157	.393	110 ± 30	103 ± 32	.194
Active IR score	3.4 ± 1.4	3.0 ± 1.7	.109	.362	3.8 ± 1.3	3.6 ± 2.0	.450
Active ER (°)	25 ± 20	18 ± 19	**.019**	.187	29 ± 20	20 ± 18	**.007**
SST score	5.4 ± 3.1	5.0 ± 2.8	.322	.536	5.4 ± 3.0	5.1 ± 3.0	.621
Constant score	41.7 ± 12.8	41.2 ± 11.9	.804	.899	43.4 ± 13.6	43.2 ± 13.9	.938
ASES score	42.1 ± 16.7	41.5 ± 16.9	.809	.899	40.9 ± 15.6	44.1 ± 17.8	.304
UCLA score	15.3 ± 4.1	15.3 ± 3.7	.949	.949	15.6 ± 4.2	16.1 ± 3.9	.534
SPADI score	74.0 ± 25.3	75.5 ± 21.6	.683	.899	74.6 ± 23.5	72.2 ± 22.8	.550
SAS score	50.6 ± 10.1	47.7 ± 11.0	.101	.362	52.0 ± 10.4	50.8 ± 11.5	.543
Postoperative							
Active abduction (°)	141 ± 25	132 ± 26	.055	.182	146 ± 26	141 ± 25	.243
Active FE (°)	154 ± 19	153 ± 16	.707	.707	160 ± 20	158 ± 12	.385
Active IR score	5.4 ± 0.9	5.1 ± 1.3	.091	.182	5.7 ± 0.9	5.5 ± 0.9	.222
Active ER (°)	57 ± 14	46 ± 17	**<.001**	**.001**	62 ± 13	49 ± 19	**<.001**
SST score	11.5 ± 1.0	11.1 ± 1.5	.080	.182	11.6 ± 0.7	11.1 ± 1.2	**.019**
Constant score	78.9 ± 8.6	77.7 ± 7.7	.357	.397	80.2 ± 8.1	80.2 ± 6.8	.966
ASES score	95.3 ± 9.6	92.6 ± 12.2	.167	.239	95.2 ± 7.6	92.3 ± 10.4	.102
UCLA score	33.2 ± 2.3	32.8 ± 2.3	.292	.364	33.5 ± 1.9	33.1 ± 1.8	.175
SPADI score	5.8 ± 10.6	9.4 ± 16.4	.150	.239	4.8 ± 7.9	9.1 ± 11.0	**.022**
SAS score	86.0 ± 6.4	82.8 ± 6.9	**.004**	**.021**	88.3 ± 5.1	84.9 ± 5.5	**.001**
Improvement							
Active abduction (°)	53 ± 32	49 ± 32	.413	.793	52 ± 34	58 ± 37	.381
Active FE (°)	52 ± 29	55 ± 29	.573	.793	51 ± 31	55 ± 33	.476
Active IR score	2.1 ± 1.4	2.1 ± 1.6	.854	.945	2.0 ± 1.2	1.9 ± 1.7	.972
Active ER (°)	33 ± 21	27 ± 20	.100	.793	34 ± 21	29 ± 21	.224
SST score	6.3 ± 3.1	6.3 ± 2.6	.945	.945	6.3 ± 3.0	6.1 ± 2.9	.750
Constant score	37.3 ± 13.0	36.0 ± 12.3	.524	.793	36.5 ± 14.1	36.4 ± 14.0	.977
ASES score	53.2 ± 19.0	51.2 ± 19.3	.505	.793	54.5 ± 17.4	48.2 ± 19.1	.060
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Complications	0.5% (1)	0.0% (0)	1.000	-	0.0% (0)	0.0% (0)	1.000
Required revision surgery	0.5% (1)	0.0% (0)	1.000	-	0.0% (0)	0.0% (0)	1.000

ASES, American shoulder and elbow surgeons; aTSA, anatomic total shoulder arthroplasty; ER, external rotat FE, forward elevation; IR, internal rotation; rTSA, reverse total shoulder arthroplasty; SAS, shoulder arthropla smart; SPADI, shoulder pain and disability index; Subscapularis, subscapularis; SST, simple shoulder test. Values represent mean ± standard deviation unless otherwise noted. Bold indicates statistical significance.

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