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# Hemiarthroplasty versus total shoulder arthroplasty in B2 glenoids with an intact rotator cuff: a long-term matched cohort analysis

Ryan T. Conyer, MD[a], James R. Markos, MD[a], Erick M. Marigi, MD[a], Robert A. Cates, DO[a], Scott P. Steinmann, MD[a,b], John W. Sperling, MD[a,*]

[a]Department of Orthopedic Surgery, Mayo Clinic, Rochester, MN, USA
[b]Department of Orthopedic Surgery, University of Tennessee, Chattanooga, TN, USA

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**Background:** Walch B2 glenoids present unique challenges to the shoulder arthroplasty surgeon, particularly in young, active patients who may wish to avoid the restrictions typically associated with an anatomic total shoulder arthroplasty (TSA). Long-term data are limited when comparing hemiarthroplasty (HA) and TSA for patients with an intact rotator cuff. The purpose of our study was to compare the long-term outcomes of HA vs. TSA in a matched analysis of patients with B2 glenoids, primary osteoarthritis (OA), and an intact rotator cuff.

**Methods:** A retrospective review was performed of all patients who underwent HA or TSA between January 2000 and December 2011 at a single institution. Inclusion criteria were primary OA, Walch B2 glenoid morphology, an intact rotator cuff intraoperatively, at least 2 years of clinical follow-up, or revision within 2 years of surgery. Fifteen HAs met inclusion criteria and were matched 1:2 with 30 TSAs using age, sex, body mass index, and implant selection. Clinical outcomes including range of motion (ROM), visual analog scale (VAS) for pain, subjective shoulder value score, American Shoulder and Elbow Surgeons (ASES) score, complications, and revisions were recorded. Postoperative radiographs were reviewed to assess for stem loosening, humeral head subluxation, glenoid loosening, and glenoid erosion.

**Results:** A total of 15 HAs and 30 TSAs met inclusion criteria at a mean follow-up of 9.3 years. The mean age at the time of surgery was 60.2 years for HA and 65.4 years for TSA ($P = .08$). Both cohorts had significant improvements in ROM, subjective shoulder value, and VAS pain scores ($P < .001$). TSA had higher postoperative ASES scores compared to HA ($P = .03$) and lower postoperative VAS pain scores ($P = .03$), although the decrease in pain from preoperatively to final follow-up was not significantly different between HA and TSA ($P = .11$). HAs were more likely to have posterior humeral subluxation ($P < .001$) and stem lucencies ($P = .02$). Revisions occurred in 11.1% of the cohort with no difference for HA and TSA ($P = .73$).

**Conclusions:** At nearly 10 years of follow-up, HA and TSA both showed significant improvements in ROM and pain when performed for primary glenohumeral OA in B2 glenoids with intact rotator cuffs. Compared to HA, TSAs had less posterior humeral subluxation, less stem lucencies, higher ASES scores, and lower postoperative VAS pain scores. However, our study failed to demonstrate a difference in ROM, complication, or revision rates between HA and TSA.

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Glenoid morphology is an important consideration for the shoulder arthroplasty surgeon when determining a treatment choice for patients with glenohumeral osteoarthritis (OA).[22,23] The Walch B2 glenoid morphology was originally described by Walch et al on axial computed tomography (CT) scans as posterior humeral head subluxation with glenoid retroversion and a posterior glenoid cupula leading to a biconcave glenoid appearance.[31] Of the 113 patients in the original Walch cohort with glenohumeral OA, 32% had a B2 glenoid. A biconcave appearance is the hallmark of the B2 glenoid and distinguishes it from B1 glenoids which have posterior humeral subluxation with posterior joint space narrowing, and the later-described B3 glenoids which have a monoconcave appearance with at least 15° of retroversion and/or at least 70% posterior humeral head subluxation.[2,3,6,13]

This study was approved by the institutional review board of the Mayo Clinic.

*Corresponding author: John W. Sperling, MD, Department of Orthopedic Surgery, Mayo Clinic, 200 1st Street SW, Rochester, MN 55905, USA.

*E-mail address:* sperling.john@mayo.edu (J.W. Sperling).

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The B2 glenoid typically has posteroinferior erosion which creates unique challenges for the shoulder arthroplasty surgeon including compromised glenoid bone stock, excessive glenoid retroversion, and posterior humeral head subluxation. A recent systematic review discussed surgical treatment and reconstructive options for patients with glenohumeral arthritis and a Walch B2 glenoid including arthroscopic débridement, hemiarthroplasty (HA), anatomic total shoulder arthroplasty (TSA), and reverse shoulder arthroplasty (RSA).[21] While RSA has emerged as an effective reconstruction option for patients with rotator cuff tear arthropathy among other indications,[34] HA and TSA are commonly considered for patients with an intact rotator cuff.

The decision between HA and TSA for younger, more active patients with an intact rotator cuff may be determined in part by the younger patient's willingness or lack thereof to adhere to the postoperative restrictions typically associated with a TSA. However, prior studies have demonstrated less predictable pain relief and functional outcomes for HA compared to TSA even in the young, active patient population.[1,4,7,11,28] More recently, Wang et al showed similar long-term outcomes for HA and TSA in 16 patients with avascular necrosis of the humeral head.[32] Long-term data are limited comparing HA and TSA for patients with B2 glenoids and an intact rotator cuff. Therefore, the purpose of our study was to compare the long-term outcomes of HA vs. TSA in a matched analysis of patients with B2 glenoids, primary OA, and an intact rotator cuff.

## Methods

Following institutional review board approval, a retrospective review was performed for all patients in our prospectively gathered joint registry database who underwent HA or TSA between January 2000 and December 2011 by either of the senior authors (S.P.S. or J.W.S.). Inclusion criteria were primary OA of the glenohumeral joint, B2 glenoid morphology as per the Walch classification, availability of a preoperative axial CT scan, an intact rotator cuff as confirmed by direct visualization at the time of surgery, and at least 2 years of clinical follow-up. Patients revised less than 2 years after primary arthroplasty were also included.

Between January 2001 and December 2011, the 2 senior authors (J.W.S. and S.P.S.) performed 981 HAs and TSAs at a single institution. A total of 844 patients had preoperative CT scans available for review. Subsequently, 184 B2 glenoids were identified on preoperative axial CT. Patients were excluded if they had a rotator cuff tear identified at the time of surgery (n = 33), less than 2 years of clinical follow-up (n = 5), post-traumatic etiology of arthritis (n = 3), glenoid reaming in cases of HA (n = 2), a known diagnosis of rheumatoid arthritis (n = 2), or acute fracture (n = 1). After exclusions, 15 HAs and 123 TSAs remained. The 15 HAs were then matched 1:2 with 30 TSAs based on age, sex, body mass index (BMI), and implant selection. Therefore, the final cohort consisted of 45 patients.

Follow-up was performed at 6 weeks, 1 year, 2 years, and 5 years, as well as every 5 years thereafter. For patients unable to present physically, shoulder evaluations were completed with a validated outcomes questionnaire along with radiographs.[27] A concurrent review of the electronic medical record and our total joint registry database was performed to obtain clinical outcomes. These included the preoperative and postoperative visual analog scale (VAS) pain score; subjective shoulder value (SSV) score; active range of motion (ROM) measurements assessed in 3 planes including forward elevation (FE), external rotation (ER), and internal rotation (IR); postoperative complications; and implant survivorship free from reoperations or revisions. American Shoulder and Elbow Surgeons (ASES) Shoulder Assessment Form scores were not available preoperatively, so postoperative values were compared between HA and TSA cohorts. FE and ER were measured in degrees, while IR was measured as the level reached by the thumb as per the scale of Flurin et al.[8]

For each shoulder, radiographs (Grashey view in ER and axillary view) were collected at the preoperative mark, at 6 weeks postoperatively, and at final follow-up. Preoperatively, CT scans reformatted in the axial plane were also acquired. Preoperative glenoid morphology was classified as per the modified Walch classification. Glenoid version was measured on CT scans as per the technique by Friedman et al.[9] Preoperative and postoperative humeral head subluxation was classified as per the method described by Torchia et al.[30] Postoperative radiolucencies of the glenoid component were graded as per the Lazarus classification.[16] Postoperative radiolucencies of the stem were graded as per the method described by Sanchez-Sotelo et al.[26]

Paired *t*-tests were used to compare continuous variables between the preoperative and postoperative periods for the entire cohort. Changes in preoperative to postoperative values for the outcome variables were compared between the HA and TSA cohorts using two-sample *t*-tests. Reoperation-free survivorship estimates were calculated using the Kaplan-Meier method (all reoperations were revisions). A $P$ value of < .05 was considered statistically significant, and no multiple testing corrections were applied. All statistical analyses were performed using SAS Studio software (version 3.81 Basic Edition; SAS Institute, Cary, NC, USA).

## Results

### Demographics

A total of 45 shoulders in 45 patients met the inclusion criteria for final data analysis. There were 35 male shoulders (77.8%) and 10 female shoulders (22.2%). The mean age at surgery was 63.6 ± 9.3 years, and the mean BMI was 30.2 ± 3.9 kg/m$^2$. A total of 39 shoulders had no prior nonarthroplasty shoulder surgeries (86.7%), whereas 6 shoulders had at least 1 prior nonarthroplasty shoulder surgery (13.3%). For the 2 shoulders with more than 1 prior procedure, these both comprised a single surgical episode with more than 1 procedure performed. Prior surgeries included arthroscopic débridement (n = 4), capsulorrhaphy (n = 2), diagnostic arthroscopy alone (n = 1), loose body removal (n = 1), and acromioplasty (n =1). Implant use included 33 Biomet (73.3%), 10 Richards Cofield 2 (22.2%), and 2 Tornier (4.4%). All stems were press-fit. All glenoid components had either cemented or hybrid fixation. There were no significant differences between the HA and TSA cohort for age, sex, BMI, or implant selection. The remainder of the demographic data is summarized in Table I.

### Clinical outcomes

At a mean follow-up period of 9.3 ± 3.9 years, significant improvements were observed with respect to the VAS pain score (8.9 to 2.1, $P < .001$), SSV score (18.7 to 67.6, $P < .001$), active FE (95.3° to 130.8°, $P < .001$), active ER (12.9° to 41.6°, $P < .001$), and active IR score (1.9 to 4.2, $P < .001$). There were no differences between patients who underwent HA and those who underwent TSA for the improvement in active FE, active ER, active IR, or SSV as summarized in Table II. Mean postoperative VAS pain scores were lower for TSA than HA ($P = .03$), although TSA patients started with a slightly lower pain score and the change in VAS pain score was not significantly different between the cohorts ($P = .11$). The mean postoperative ASES score was 72.2 ± 15.6 for the HA group and 84.5 ± 14.2 ($P = .03$).

**Table I**
Patient demographics and surgical characteristics.

| Variable | Total (n = 45) | HA (n = 15) | TSA (n = 30) | *P* value |
|---|---|---|---|---|
| Age, y | 63.6 ± 9.3 | 60.2 ± 12.6 | 65.4 ± 6.8 | .08 |
| Sex | | | | |
| Male | 35 (77.8) | 12 (80.0) | 23 (76.7) | .80 |
| Female | 10 (22.2) | 3 (20.0) | 7 (23.3) | .80 |
| BMI, kg/m$^2$ | 30.2 ± 3.9 | 29.7 ± 4.4 | 30.4 ± 3.8 | .58 |
| Laterality | | | | |
| Right | 32 (71.1) | 10 (66.7) | 22 (73.3) | .64 |
| Left | 13 (28.9) | 5 (33.3) | 8 (26.7) | .64 |
| Tobacco | 0 (0.0) | 0 (0.0) | 0 (0.0) | - |
| Diabetes | 0 (0.0) | 0 (0.0) | 0 (0.0) | - |
| Previous procedures* | | | | |
| 0 | 39 (86.7) | 11 (73.3) | 28 (93.3) | .06 |
| 1 | 4 (8.9) | 2 (13.3) | 2 (6.7) | .74 |
| 2 | 1 (2.2) | 1 (6.7) | 0 (0.0) | - |
| 3 | 1 (2.2) | 1 (6.7) | 0 (0.0) | - |
| Implant | | | | |
| Biomet | 33 (73.3) | 10 (66.7) | 23 (76.7) | .47 |
| Richards Cofield 2 | 10 (22.2) | 4 (26.7) | 6 (20.0) | .61 |
| Tornier | 2 (4.4) | 1 (6.7) | 1 (3.3) | .61 |
| Final follow-up, y | 9.3 ± 3.9 | 8.0 ± 4.3 | 9.9 ± 3.7 | .13 |

*HA*, hemiarthroplasty; *TSA*, total shoulder arthroplasty; *BMI*, body mass index.
The values are given as mean ± standard deviation or n (%).
*Nonarthroplasty procedures on ipsilateral shoulder.

**Table II**
Comparison of clinical outcomes in patients with HA vs. TSA.

| Variable | HA (n = 15) | TSA (n = 30) | *P* value |
|---|---|---|---|
| Preoperative FE, ° | 87.7 ± 28.0 | 98.7 ± 31.7 | .29 |
| Postoperative FE, ° | 127.7 ± 26.8 | 132.3 ± 39.2 | .68 |
| Δ FE, °* | 43.5 ± 35.4 | 33.7 ± 56.0 | .56 |
| Preoperative ER, ° | 16.9 ± 14.4 | 11.1 ± 14.2 | .23 |
| Postoperative ER, ° | 38.0 ± 15.2 | 43.3 ± 25.1 | .45 |
| Δ ER, ° | 23.1 ± 18.4 | 32.9 ± 29.2 | .28 |
| Preoperative IR score | 1.7 ± 1.7 | 2.0 ± 1.7 | .59 |
| Postoperative IR score | 4.1 ± 1.4 | 4.2 ± 1.7 | .84 |
| Δ IR score | 2.6 ± 2.0 | 2.4 ± 2.2 | .72 |
| Preoperative SSV | 16.0 ± 7.4 | 20.0 ± 10.8 | .21 |
| Postoperative SSV | 60.0 ± 30.9 | 71.3 ± 25.3 | .20 |
| Δ SSV | 44.0 ± 29.9 | 51.3 ± 27.9 | .42 |
| Preoperative VAS | 9.2 ± 1.0 | 8.8 ± 0.9 | .15 |
| Postoperative VAS | 3.2 ± 2.3 | 1.6 ± 2.1 | **.03** |
| Δ VAS | −6.0 ± 2.5 | −7.2 ± 2.1 | .11 |
| Postop ASES score | 72.2 ± 15.6 | 84.5 ± 14.2 | **.03** |
| Complications† | 2 (13.3) | 6 (20.0) | .58 |
| Arthrofibrosis | 1 (6.7) | 0 (0.0) | - |
| Glenoid loosening | - | 3 (10.0) | - |
| Rotator cuff tear | 0 (0.0) | 3 (10.0) | - |
| Glenohumeral dislocation | 0 (0.0) | 1 (3.3) | |
| Painful glenoid arthrosis | 1 (6.7) | - | - |
| Revisions | 2 (13.3) | 3 (10.0) | .73 |

*HA*, hemiarthroplasty; *TSA*, total shoulder arthroplasty; *FE*, forward elevation; *ER*, external rotation; *IR*, internal rotation; *SSV*, subjective shoulder value; *VAS*, visual analog scale for pain; *ASES*, American Shoulder and Elbow Surgeons.
The values are given as mean ± standard deviation or n (%).
Significant P values <.05 are shown in bold.
*Delta values were calculated as the mean of the change from preoperative to postoperative values for each patient.
†Complications are reported by number of patients. Complications categories are reported by number of events.

### *Radiographic outcomes*

Preoperative imaging was obtained in all patients (Table III). The glenoid morphology was confirmed to be Walch B2 in all 45 patients. Mean glenoid retroversion was 15.8°. All shoulders had posterior humeral head subluxation, consistent with the Walch description of B2 glenoids. Preoperative subluxation was mild in 31.1%, moderate in 53.3%, and severe in 15.6%. Complete postoperative radiographic data were available for all 45 shoulders.

**Table III**
Comparison of preoperative and postoperative radiographic outcomes in patients with HA vs. TSA.

| Variable | HA (n = 15) | TSA (n = 30) | *P* value |
|---|---|---|---|
| Preoperative | | | |
| Glenoid retroversion, ° | 16.8 ± 11.4 | 15.3 ± 7.1 | .58 |
| Humeral head subluxation | | | |
| None | 0 (0.0) | 0 (0.0) | - |
| Mild | 2 (13.3) | 12 (40.0) | .07 |
| Moderate | 9 (60.0) | 15 (50.0) | .53 |
| Severe | 4 (26.7) | 3 (10.0) | .15 |
| Glenoid erosion | | | |
| None | 0 (0.0) | 0 (0.0) | - |
| Mild | 5 (33.3) | 15 (50.0) | .29 |
| Moderate | 9 (60.0) | 15 (50.0) | .53 |
| Severe | 1 (6.7) | 0 (0.0) | - |
| Postoperative | | | |
| Humeral head subluxation | | | |
| None | 1 (6.7) | 17 (56.7) | **<.001** |
| Mild | 7 (46.7) | 6 (20.0) | .06 |
| Moderate | 5 (33.3) | 4 (13.3) | .11 |
| Severe | 2 (13.3) | 3 (10.0) | .74 |
| Glenoid erosion | | | |
| None | 0 (0.0) | - | - |
| Mild | 3 (20.0) | - | - |
| Moderate | 11 (73.3) | - | - |
| Severe | 1 (6.7) | - | - |
| Stem radiolucent lines | 4 (26.7) | 1 (3.3) | **.02** |
| Glenoid radiolucent lines | - | 10 (33.3) | - |
| Glenoid loosening | - | 3 (10.0) | - |

*HA*, hemiarthroplasty; *TSA*, total shoulder arthroplasty.
The values are given as mean ± standard deviation or n (%).
Significant P values <.05 are shown in bold.

Postoperatively, HAs were significantly more likely to have at least mild posterior humeral head subluxation compared to TSA ($P$ < .001). Stem lucencies were significantly more common in the HA group ($P$ = .02). All 4 stem lucencies in the HA group occurred in zone 1 and had a mean size of 1.25 mm. The stem lucency in the TSA group occurred in zone 5 and was 1 mm wide. Glenoid radiolucent lines were present in 10 TSAs (33.3%). Glenoid lucency was graded as Lazarus grade 1 in 6 TSAs (20.0%), grade 2 in 1 TSA (3.3%), and grade 5 in 3 TSAs (10.0%). The Lazarus grade 5 glenoids were considered loose at a mean of 13.7 years after surgery (range 10.1 to 16.6 years). Only 1 of the 3 loose glenoid components underwent revision. Of the other 2, 1 patient had glenoid loosening which was discovered incidentally during a trauma workup after a fall. The patient was asymptomatic regarding his shoulder. Another patient was seen in routine follow-up and was also asymptomatic regarding her loose glenoid component.

### *Complications and revisions*

There were 9 complications in 8 patients (17.8%) during the follow-up period as summarized in Table II. Two patients in the HA cohort had an observed complication during follow-up compared to 6 patients in the TSA cohort (13.3% vs. 20.0%, $P$ = .58). The 2 complications seen in the HA group were arthrofibrosis leading to persistent pain and decreased ROM, as well as 1 patient with progressive painful glenoid wear. Glenoid loosening and rotator cuff tears were the most common complications seen in the TSA cohort and were each present in 10.0% of the TSAs. Glenoid loosening occurred at a mean of 13.7 years postoperatively as mentioned previously. The 3 rotator cuff tears were identified at a mean of 7.8 years postoperatively (range 1.1 to 14.7 years).

A total of 5 reoperations (11.1%) occurred throughout the follow-up period, all of which were revisions. Two HAs were revised to TSA. One was performed at an outside institution 4.5 years

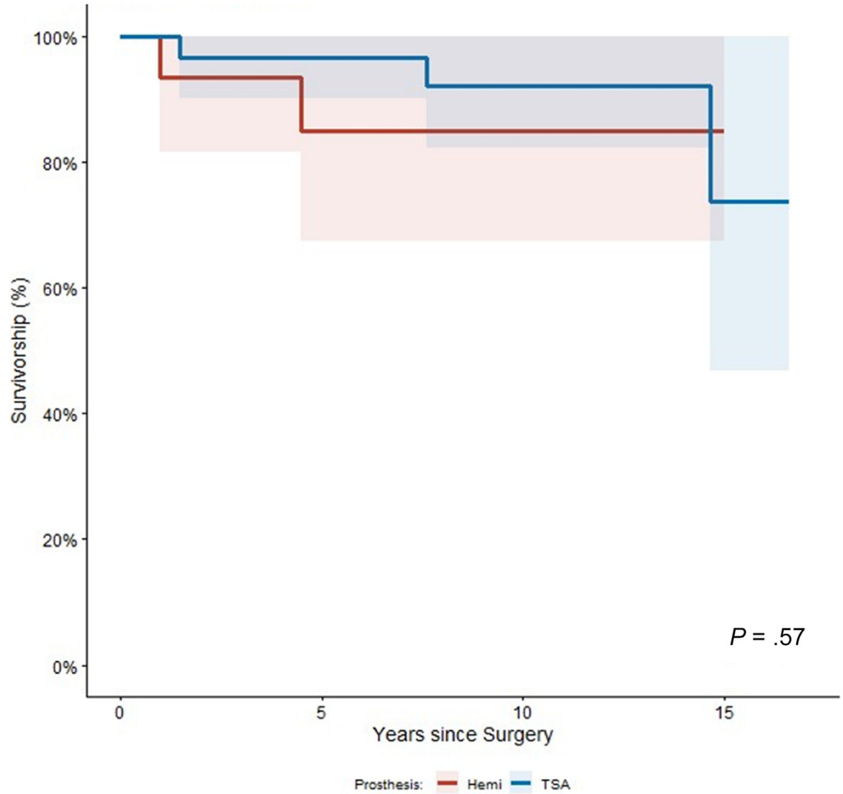


**Figure 1** Kaplan-Meier survivorship estimates for HA vs. TSA. *HA*, hemiarthroplasty; *Hemi*, hemiarthroplasty; *TSA*, total shoulder arthroplasty.

postoperatively for arthrofibrosis leading to pain and decreased ROM. The other was performed at 11.6 months postoperatively for progressive painful glenoid wear. Three TSAs were revised to RSA at a mean 7.9 years after primary arthroplasty (range 1.5 to 14.6 years). Indications for revision included glenoid loosening, rotator cuff tear, and posterior glenohumeral dislocation after a fall. There were no statistically significant differences in rate of revision for HA vs. TSA (13.3% vs. 10.0%, $P = .73$) or for the Kaplan-Meier 10-year survivorship estimates (84% vs. 92%, $P = .57$) as seen in Table II and Figure 1.

## Discussion

Many variables are involved in the surgical decision-making for patients with Walch B2 glenoid morphology and glenohumeral OA.[21] HA and TSA are 2 common surgical options for these patients, and the final construct may be chosen based upon patient age, the presence or absence of a rotator cuff tear, and patient and surgeon preference. The patient cohorts in much of the available literature comparing HA and TSA have been quite heterogeneous and have therefore led to continued debate over the most appropriate treatment for primary glenohumeral OA.[1] There is a paucity of literature comparing HA and TSA for patients with B2 glenoids. Therefore, our study created a homogeneous matched cohort of patients with B2 glenoid morphology, primary glenohumeral OA, an intact rotator cuff, and a minimum follow-up of 2 years.

The findings of our study indicate excellent clinical and radiographic outcomes for both HA and TSA. In this cohort of 45 patients with mean follow-up of almost 10 years, only 5 patients underwent revision surgery. The estimated 10-year survival rate was 84% for HA and 92% for TSA. This did not reach statistical significance, although the event rate for analysis was very low. Our revision rate is consistent with reports in the literature of 0%-30% of patients undergoing revision following HA or TSA.[15,17,21,24,25,29] Some studies have suggested improved pain and functional relief with TSA compared to HA.[4,10,14,18,28] For example, the study by Iannotti et al demonstrated improved outcomes for TSA in the domains of function, pain, and ASES score in the absence of posterior subluxation.[14] In patients with preoperative posterior subluxation such as that seen in B2 glenoids, ASES, pain, and ER were worse than those without posterior subluxation and were similar between patients with HA and TSA. Our study did demonstrate better postoperative ASES scores and VAS pain scores for the TSA cohort, although it should be noted that the TSA cohort started with slightly lower VAS pain scores and the decrease in VAS pain scores between the cohorts was not significantly different. We did not have ASES scores preoperatively, and it is possible that the difference in postoperative ASES scores between the HA and TSA cohorts was strongly influenced by the domain of pain given the lack of a significant difference in ROM and SSV.

While long-term data on HA for patients with eccentric glenoid wear are not thoroughly reported, one recent study by Levine et al reported unfavorable outcomes in 16 patients with eccentric glenoids who underwent HA.[17] This study reported a revision rate of more than 30% in these patients, much more than the 13.3% in our cohort. However, only 3 of the patients in the Levine study had primary OA, while the other 13 had secondary OA. Our study demonstrates similar excellent clinical outcomes between HA and TSA with regards to both revision rate and pain and functional outcomes. A study by Edwards et al reported outcomes from multiple centers for patients with concentric vs. eccentric glenoids and HA vs. TSA.[7] In their study cohort of patients with eccentric glenoids, TSA performed better than HA for mobility, active elevation, and gain in active ER. However, the mean follow-up was only 3 years and there was significant surgeon heterogeneity, as it compared patients from 55 centers throughout Europe and South Africa. Additionally, the timeline of this study was 1991-1998, and there have been many technical and implant-related advances since then which could affect the outcomes. Our patients were sampled from 2 surgeons at a single institution between the years 2000 and 2011. This timeline was intentionally selected to allow for at least 10 years of potential follow-up for each patient while remaining relevant in the current era of shoulder arthroplasty.

Many studies analyzing HA and TSA in the setting of eccentric glenoid wear investigated modified surgical techniques for correcting the glenoid eccentricity. For example, several studies have analyzed the effects of glenoid reaming in the setting of HA.[11,12,20,33] This is performed to alleviate the biconcave and retroverted nature of these glenoids. By correcting the biconcavity and reducing the retroversion, the potential negative outcomes of progressive posterior subluxation and progressive posterior glenoid erosion may be reduced. However, Gilmer et al reported improvement in functional scores for only 23% of patients with biconcave glenoids who underwent HA with glenoid reaming.[12] Getz et al showed good to excellent results in only 52% of patients with this technique.[11] Our study excluded any patients who underwent HA with glenoid reaming to further reduce the heterogeneity of our population. Despite not performing concentric reaming, the percentage of patients with severe glenoid erosion did not change from preoperatively to postoperatively (6.7% vs. 6.7%). Additionally, severe humeral head subluxation decreased from 26.7% preoperatively to 13.3% postoperatively. However, HAs were significantly more likely to have at least mild posterior humeral head subluxation compared to TSA ($P < .001$). Despite the greater posterior humeral head subluxation for HAs, we did not demonstrate significant differences in ROM, change in VAS pain, or revision for HA and TSA. This suggests that progressive glenoid erosion and posterior subluxation may be avoided in HA without performing concentric reaming and that the increased humeral head subluxation seen in HA compared to TSA may not lead to adverse outcomes.

The predominant cause for revision TSA is glenoid component loosening. One recent systematic review demonstrated at least some degree of glenoid loosening in 42% of patients who underwent TSA.[19] In our study, 33% of TSAs were found to have radiolucent lines at latest radiographic follow-up. However, only 10% had definitive loosening as defined by Lazarus grade 5. Of these 3 patients, 2 were asymptomatic and 1 underwent revision to RSA. Humeral radiolucent lines were more common in HA than TSA (26.7% vs. 3.3%, $P = .02$). This is contrasted with the study by Sperling et al in which humeral periprosthetic lucencies were more common in TSA than HA (60% vs. 34%).[28] The significance of this is unclear as 4 of the 5 radiolucent lines were 1 mm wide and the other was 2 mm wide. These patients did not have significant differences in pain or functional scores compared to those without stem lucencies.

While our study focused on primary glenohumeral OA as an indication for shoulder arthroplasty, several recent studies have demonstrated favorable outcomes for HA when performed for avascular necrosis of the humeral head.[5,32] The investigation by Cheema et al reported a complication rate of 4% and revision rate of 3% for these patients at mean 6 years of follow-up. Additionally, only 2% of patients had severe postoperative humeral head subluxation and 7% had severe glenoid erosion.[5] Similarly, Wang et al reported a more than 80% survivorship for 16 shoulders undergoing either HA or TSA at 10 years postoperatively.[32] They also demonstrated similar improvements in pain and function between HA and TSA. The only significant difference was in IR, with TSA showing superior improvement compared to HA. While our study analyzed only patients with primary glenohumeral OA, we also failed to demonstrate significant differences between HA and TSA for ROM, complication, and revision rate. FE and IR scores were slightly better for HA compared to TSA for our cohort, with FE improving by 43 degrees for HA and 34 degrees for TSA. IR scores improved by 2.6 points for HA compared to 2.4 points for TSA. Neither of these measures reached statistical significance. VAS pain scores decreased more for TSA compared to HA (−7.2 vs. −6.0, $P = .11$) and ASES scores at final follow-up were higher for TSA (84.5 vs. 72.2, $P = .03$).

Our study does have limitations. First, it has the limitations inherent to retrospective studies. These include heterogeneity of surgical techniques and rehabilitation protocols, although these differences are minimal for the surgeons in the present study. Strict inclusion and exclusion criteria were applied, and matching was performed to create a homogeneous cohort for comparison. Second, the cohort in this study was quite young at a mean of 63.6 years due to our matching of the TSAs to HAs. This was performed to eliminate age as a confounding variable but could make the TSA cohort less generalizable to an older TSA candidate. Third, preoperative ASES scores were not available, so we instead compared the ASES scores between the 2 cohorts at final follow-up. Finally, our sample size of 45 patients could have been a limiting factor for the observance of statistically significant outcomes. However, comparing homogeneous matched groups with minimal confounding variables was determined to be more valuable than comparing a large, heterogeneous sample.

## Conclusion

At nearly 10 years of follow-up, HA and TSA both showed significant improvements in ROM and pain when performed for primary glenohumeral OA in B2 glenoids with intact rotator cuffs. Compared to HA, TSAs had less posterior humeral subluxation, less stem lucencies, higher ASES scores, and lower postoperative VAS pain scores. However, our study failed to demonstrate a difference in ROM, complication, or revision rates between HA and TSA.

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