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# Treatment options for complex shoulder osteoarthritis with posterior humeral head subluxation and glenoid bone loss (Walch B): A systematic review

Michael J. Scarcella, MD[a,*], Sercan Yalcin, MD[a], Eyal Ginesin, MD[b], Ronak Patel, MD[b], Anthony Miniaci, MD, FRCSC[a]

[a]Cleveland Clinic Orthopaedic and Rheumatology Institute, Avon, OH, USA
[b]Hinsdale Orthopaedic, Hinsdale, IL, USA

A R T I C L E I N F O

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B glenoid
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*Level of evidence:* Level IV; Systematic Review

**Background:** Shoulder osteoarthritis (OA) with eccentric (B) glenoids has generally been associated with poor patient-reported outcomes and increased complications. The purpose of this study was to outline all the described treatment options and their outcomes and complications in order to better guide treatment.
**Methods:** This systematic review was performed according to the Preferred Reporting Items for Systematic review and Meta-analysis guidelines. Searches were performed up to December 19, 2019, using Medline, EMBASE, Scopus, and Cochrane databases. Inclusion criteria included studies for glenohumeral OA reporting posterior humeral head subluxation and/or posterior glenoid erosion. Studies were excluded if they were review papers, abstracts, or conference papers; had heterogeneity of included Walch types; or were not written in English.
**Results:** Twenty-one studies met inclusion criteria. The mean follow-up duration was 47.5 months (range, 14-300), and the mean patient age 62 years (38-88). Six different discernible techniques were identified: asymmetric reaming with onlay glenoid (AROG) in 267 shoulders, posterior glenoid bone grafting (PGBG) with onlay glenoid in 79 shoulders, augmented glenoid (AG) in 160 shoulders, reverse shoulder arthroplasty (RSA) with or without bone grafting in 118 shoulders, hemiarthroplasty with concentric reaming (HACR) in 57 shoulders, and humeral head arthroplasty with inlay glenoid (HAIG) in 36 shoulders. All techniques reported improved patient outcomes and range of motion. Short-term (<5 years) studies reported glenoid loosening leading to revisions in 3% of AROG, 2.7% PGBG, 0.8% AG, 1.4% RSA, and 0% HAIG shoulders. HACR had a high revision rate (12.3%) due to persistent pain and stiffness. Midterm (>5 years) studies demonstrated increased rates of glenoid loosening with AROG (14.5%), PGBG (21% loose, 23.8% "at risk"), and AG (18.9% "at risk"), as well as increased rates of subluxation or revision due to instability. HAIG did not demonstrate loosening, subluxation, or revision at 55.2 months
**Conclusion:** Various techniques exist to manage complex primary glenohumeral OA with posterior subluxation and posterior glenoid erosion. Glenoid component survival is a concern with ASOG, PGBG, and AG. HACR has the highest early revision rate. RSA offers promising short-term and midterm results likely due to the advantage of more secure fixation as well as a constrained design to prevent posterior subluxation. HAIG has the lowest complication and revision rates although further long-term studies are needed.



Total shoulder arthroplasty (TSA) is performed annually in the United States in over 40,000 patients, which is doubling every 7 years.[28,44] Good to excellent results have been reported in up to 95% of patients, with a revision rate of about 7%.[3,38] Alternatively, reverse shoulder arthroplasty (RSA) has been used to address etiologies associated with rotator cuff deficiency; however, the indications have recently expanded to address primary glenohumeral osteoarthritis (GHOA) with bone loss.[35] Revision-free survival at 10 years is between 89% and 93% for RSA.[2,12,17]

Despite overall success, complication and revision rates are not negligible. One of the most common causes of revision surgery was

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*Corresponding author: Michael J. Scarcella, MD, Cleveland Clinic Richard E. Jacobs Health Center, 33100 Clveland Clinic Blvd./AVW 1-1, Avon, OH 44011, USA.
*E-mail address:* scarcem@ccf.org (M.J. Scarcella).

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found to be glenoid component failure, and these complications are increased in cases of eccentric glenoid bone loss.[9,27,38,50]

Humeral head (HH) subluxation with or without posterior glenoid erosion is associated with progressive primary GHOA and has been described by Neer and Stanton and Matsen et al, with further characterization and classification by Walch et al.[33,36,49] Specifically, type B has been associated with increased complications and poorer outcomes.[27,50]

Currently, no consensus exists regarding the ideal management of HH subluxation with posterior glenoid erosion in the presence of GHOA. A previous systematic review by Luedcke et al has assessed only the outcomes of onlay glenoid TSA techniques in the B2 glenoids[32]; however, they did not include other available techniques in their analysis. To our knowledge, no study has organized the literature to provide a comprehensive review of all the treatment options described for this pathology. The purpose of this study was to present a review of the literature and analyze the results of various techniques used to manage complex shoulder osteoarthritis (Walch B glenoid and subtypes). Primary aims were to compare patient-reported outcome measures (PROMs), general radiographic signs of loosening or instability, and revision rates.

## Materials and methods

This systematic review summarizes the literature on clinical results of the different surgical techniques available in the treatment of GHOA with posterior HH subluxation and posterior glenoid erosion. We performed this systematic review according to the Preferred Reporting Items for Systematic review and Meta-Analysis guidelines.

### *Eligibility criteria*

Studies included patients undergoing surgery for GHOA with Walch B1, B2, and B3 glenoids, with reported clinical outcomes, and were written in English. Studies were excluded if they did not describe bone loss pattern; did not report clinical results; were review, abstracts, or conference papers; had heterogeneity of included Walch types, or were not written in English

### *Information sources*

A search strategy was constructed to retrieve the most relevant yield on surgical approaches for the GHOA with HH subluxation with or without glenoid erosion. All searches were conducted on December 11, 2019, in Medline, EMBASE, Scopus, and Cochrane databases. A combination of keywords, including truncation, and indexing terms were used. No filters or limiters were applied. The results were deduplicated using the Covidence software (Melbourne, VIC, Australia) to facilitate and manage the screening and extraction processes. Please see Supplementary Appendix S1 which includes complete search strategies for all the databases.

### *Study selection and data collection*

A total of 394 studies were filtered from all databases. First, all studies were transferred to covidence.org, 3 authors were granted access to screen the articles, and duplicates were removed. This left 267 articles to be screened. Then, 2 authors screened abstracts of all articles independently. Discrepancies between the authors were resolved by the senior author. A total of 45 articles were selected for full-text screening. Of these, 21 articles were eligible to be included into the study (Fig. 1). For the purpose of evaluation, we defined short-term studies as <5 years and midterm as >5 years.

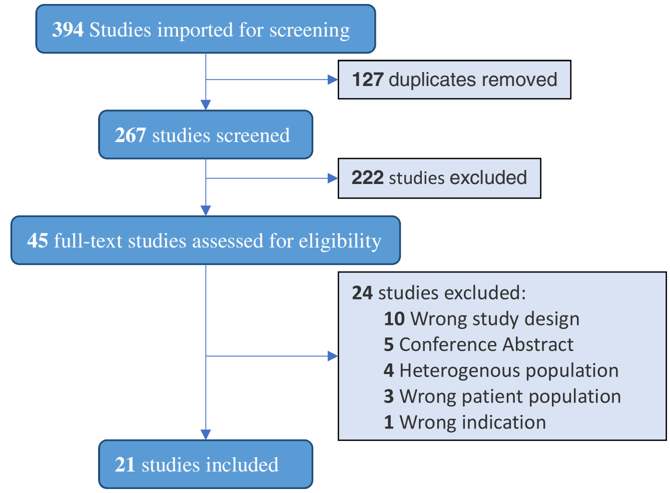


**Figure 1** STROBE diagram of search strategy of this systematic review.

### *Data items*

The extracted data included name of article, author name, name of journal, level of evidence, year, number of patients (beginning), number of shoulders (beginning), number of shoulders (follow-up), mean age (years), mean follow-up (years), number of patients with B glenoid, method of diagnosis, type of treatment, complications, radiographic lucency, and functional/pain improvement outcome.

## Results

### *Eligibility*

Forty-five full-text studies were assessed for eligibility. Twenty-one studies were included after review. Nineteen studies were level IV and 2 were level III studies.

### *Demographic characteristics*

Overall, 21 studies were reviewed with a total of 717 shoulders. Five different discernible techniques were identified and included TSA with asymmetric reaming and onlay glenoid (AROG), TSA with posterior glenoid bone grafting and onlay glenoid (PGBG), TSA with augmented glenoid components (AG), RSA with or without bone grafting, hemiarthroplasty with concentric reaming (HACR), and spherical and nonspherical HH arthroplasty with an inlay glenoid implant. All included studies had a minimum 2-year follow-up.

### *TSA with AROG*

Five studies were identified with 267 shoulders. The mean age was 66 years, and average follow-up duration was 54 months (range, 14-180).

PROMs varied among studies (Table I). The most commonly reported measure was the Constant score. The mean Constant score improved from 35.7 to 73.4.[6,14,50] Orvets et al reported improvements in American Shoulder and Elbow Surgeons (ASES) score from 35.4 to 84.3, Simple Shoulder Test (SST) score from 4.5 to 9.1, and Visual Analog Scale (VAS) pain score from 7.4 to 1.4.[40]

Four studies reported range-of-motion (ROM) measurements, with 3 providing preoperative and postoperative measurements for comparison. The mean forward flexion (FF) improved from 95° to

**Table I**
Summary of short-term studies' PROM.

| Author | LOE | Follow-up mo, mean (range) | Number B shoulders | Treatment | ASES, mean (SD) [range] | Constant, mean (SD) [range] | SST (SD) [range] | DASH (SD) [range] | SANE (SD) [range] | PSS (SD) [range] | VAS (SD) [range] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Onlay glenoid TSA | | | | | | | | | | | |
| Gerber et al (2009)[14] | 4 | 42 (NR) | 14 | Asymmetric reaming with pegged all-polyethylene glenoid | | Pre: 39 (NR) [22 to 77] Post: 78 (NR) [58-99] | | | | | |
| Alentorn-Geli et al (2018)[1] comparison TSA vs. RSA | 4 | 43 (NR) | 15 | TSA with asymmetric reaming and capsular plication | Post: 91.2 (6.7) [NR] | | Post: 10.6 (NR) [NR] | | | | |
| Orvets et al (2018)[40] | 4 | 50 (24 to 97) | 59 | Asymmetric reaming with all-polyethylene glenoid | Pre: 35.4 (14.3) [3.3 to 90] Post: 84.3 (14.0) [53.3 to 100] Improvement: 48.9 (17.5) [0 to 93.3] | | Pre: 4.5 (2.6) [0 to 12] Post: 9.1 (2.2) [4 to 12] Improvement: 4.6 (2.4) [−3 to 9] | | | | Pre: 7.4 (.17) [2 to 10] Post: 1.4 (1.9) [0-10] Improvement: 6 (2.2) [−10 to 1.5] |
| Sabesan et al (2013)[43] | 4 | 53 (26 to 110) | 9 | TSA with PGBG. All-polyethylene pegged or keel glenoid | | | | | | Pre: 38.7 (NR) [19-52] Post: 79.4 (NR) [17 to 100] | |
| Nicholson et al (2017)[37] | 4 | 48 (24 to 126) | 28 | TSA with PGBG. All-polyethylene pegged or keeled glenoid | Pre: 39 (18) [NR] Post: 90 (10) [NR] | | Pre: 4 (3) [NR] Post: 10 (2) [NR] | | | | Pre: 5 (2) [NR] Post: 1 (1) [NR] |
| Stephens et al (2017)[48] | 4 | 24* | 19 | TSA with stepped augmented all-polyethylene glenoid | Pre: 39 (NR) [NR] Post: 91 (NR) [NR] | | Pre: 2.4 (NR) [NR] Post: 10.6 (NR) [NR] | | | | Pre: 6.3 (NR) [NR] Post: 0.3 (NR) [NR] |
| Ho et al (2018)[22] | 4 | 28 (24 to 68)† | 71 | TSA with stepped augmented all-polyethylene glenoid | | | | | | Pre: 49 (NR) [5 to 66] Post: 94 (NR) [51 to 100]† | |
| Priddy et al (2019)[41] | 3 | 39 (24 to 72) | 33 | TSA with wedged augmented all-polyethylene glenoid | Pre: 45.3 (12.3) [NR] Post: 86.8 (14.7) [NR] Improvement: 41.5 (18.5) | Pre: 47.6 (15) [NR] Post: 82.7 (12.9) [NR] Improvement: 36.0 (15.9) | | | | | Pre: 5.0 (1.8) [NR] Post: 1.1 (1.7) [NR] Improvement: 4.0 (2.7) |
| RSA | | | | | | | | | | | |
| Mizuno et al (2013)[35] | 4 | 54 (24 to 139) | 27 | RSA (10 required bone grafting) | Pre: 31 (NR) [NR] Post: 76 (NR) [NR] | | | | | | |
| Harmsen et al (2017)[20] | 4 | 34 (24 to 89) | 26 | BIO-RSA | | | Pre: 29.5 (NR) [NR] Post: 89.0 (NR) [NR] Improvement: 59.5 | | Pre: 6.7 (NR) [NR] Post: 0.3 (NR) [NR] Improvement: 6.4 | | |
| Alentorn-Geli et al (2018)[1] | 4 | 35 (NR) | 16 | RSA (4 patients required bone graft) | | Post: 8.5 (NR) [NR] | | | | | |
| Hemiarthroplasty | | | | | | | | | | | |
| Hsu et al (2016)[25] | 4 | 24 (NR)minimum follow-up | 33 | Hemiarthroplasty with concentric | | | Pre: 42.5 (21.5) [NR] | | | | |

(continued on next page)

**Table I** (*continued*)

| Author | LOE | Follow-up mo, mean (range) | Number B shoulders | Treatment | ASES, mean (SD) [range] | Constant, mean (SD) [range] | SST (SD) [range] | DASH (SD) [range] | SANE (SD) [range] | PSS (SD) [range] | VAS (SD) [range] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | glenoid reaming (n = 24) | | Pre: 4.8 (2.3) [NR] Post: 10.0 (2.3) [NR] | Post: 80.5 (17.6) [NR] | | | | |
| Getz et al (2017)[15] | 4 | 24 (NR) minimum follow-up | 24 | Hemiarthroplasty with concentric glenoid reaming | | Post: 10.4 (NR) [6.0 to 12.0] only included patients not undergoing revision | Post: 74.5 (NR) [1 to 95] only included patients not undergoing revision | Post: 82.9 (NR) [38.2 to 99.0] only included patients not undergoing revision | | | |
| Inlay glenoid | | | | | | | | | | | |
| Cvetanovich et al (2019)[10] | 4 | 40 (23 to 60) | 12 | Humeral head resurfacing with inlay glenoid | | | Pre: 25.1 (20.4) [NR] Post: 80.4 (13.6) [NR] | | Pre: 5.4 (3.1) [NR] Post: 1.6 (2.3) [NR] | | |
| Egger et al (2019)[11] | 4 | 42.6 (24 to 74) | 24 | Humeral head resurfacing with inlay glenoid | | | | Pre: 42.2 (17.1) [33.1 to 51.3] Post: 88.6 (9.9) [83.3 to 93.9] | Pre: 6.4 (2.2) [5.3 to 7.5] Post: 1.0 (1.4) [0.3 to 1.7] | | |

*PROM*, Patient-reported outcome measures; *LOE*, level of evidence; *ASES*, American Shoulder and Elbow Surgeons score; *SD*, standard deviation; *SST*, Simple Shoulder Test; *DASH*, Disability of the Arm, Shoulder, and Hand; *SANE*, Single Assessment Numeric Evaluation; *PSS*, Penn Shoulder Score; *VAS*, Visual Analog Scale; *TSA*, total shoulder arthroplasty; *PGBG*, posterior glenoid bone graft; *Pre*, preoperative; *NR*, not reported; *Post*, postoperative; *RSA*, reverse shoulder arthroplasty; *BIO-RSA*, bony increased offset-reverse shoulder arthroplasty.

*Minimum 24-mo follow-up.

†Reported as median.

152°, and the mean external rotation (ER) improved from 14° to 50° (Tables I and II).[1,6,50]

Three of the studies were considered short-term follow-up (<5 years), of which 2 reported on radiographic results and complications. There was a total of 74 shoulders with 2 (3%) revisions due to glenoid loosening, and the time to revision was not reported. The mean radiographic follow-up was 37 months, and there were 4 (5%) shoulders with posterior subluxation and 29 (39%) shoulders with glenoid lucency (Table III).[1,40]

Two studies reported midterm (>5 years) radiographic follow-up and complications. There were 7 (4%) revisions due to glenoid loosening at 76 months, and 5 (2.8%) revisions due to posterior instability at 30 months. Radiographically, 26 (14.5%) glenoids were considered loose, with 11 (6.2%) having changed position. There were 18 (24%) glenoids with lucency at a mean 68.5 months (Table IV).[6,50]

### TSA with PGBG

A total of 4 studies with 79 shoulders were identified with a mean age of 59.8 years (39-87.8) and mean follow-up of 66.5 months (24-300).

PROMs varied among studies, with 1 study reporting ASES, SST, and VAS scores, and the other reporting Penn Shoulder Score.[37,43] Nicholson et al reported improvements in the mean ASES score from 39 to 90, SST score from 4 to 10, and VAS score from 5 to one.[37]

All 4 studies reported the postoperative ROM and mean ROM improvement.[29,37,43,47] Three studies demonstrated a mean postoperative FF of 151°[29,37,43] and ER of 51°.[29,37,43,47]

Two studies reported short-term follow-up in 37 shoulders (Table V). There was one (2.7%) revision due to glenoid loosening at 10 months. Radiographically, there were 8 (21.6%) shoulders noted to have broken screws or central pegs at mean 48 months; however, they were considered stable with healed bone graft, and no revisions were necessary. Two (5.4%) glenoids had reported progressive lucencies.

Two studies evaluated midterm follow-up in a total of 42 shoulders (Table VI). Radiographic follow-up at a mean 6.5 years demonstrated 15 (35.7%) glenoids with lucency, 10 (23.8%) glenoids considered at risk for failure, 9 (21.4%) asymptomatic loose glenoids, and 6 (14.3%) asymptomatic bone grafts with resorption. There were 3 (7.1%) revisions due to posterior instability within 12 months postoperatively, and 2 (4.7%) revisions due to glenoid loosening at 6 months and 60 months.[29,47]

### TSA with AG

Five studies with a total of 160 shoulders, mean age 65.2 (38-84) years and mean follow-up 47.8 months (24-228 months), were identified.

Four of the studies reported PROMs.[22,41,48] The most commonly reported scores were the ASES and VAS. Two studies reported preoperative and postoperative ASES scores, and the pooled scores improved from 42.2 to 88.9. Two studies reported VAS scores, and the scores improved from 5.65 to 0.7.[41,48] Stephens et al reported improved SST from 2.4 to 10.6.[48] Priddy et al reported an improved Constant score from 47.6 to 86.8.[41]

Three studies reported the mean FF improved from 101° to 142°. Four studies reported a mean preoperative and postoperative ER which improved from 22° to 51°.[7,41,42,48]

Three studies were considered short-term with a total of 123 shoulders. There was only 1 (0.8%) revision due to glenoid loosening at 36 months. Radiographic follow-up at a mean 30 months revealed 36 (29%) glenoids with underlying lucency and 7 (5.7%) posterior subluxations.[22,41,48]

**Table II**
Summary of long-term studies' PROM.

| Author | LOE | Follow-up mo, mean (range) | Number B shoulders | Treatment | ASES, mean (SD) [range] | Constant, mean (SD) [range] | SST (SD) [range] | DASH (SD) [range] | SANE (SD) [range] | PSS (SD) [range] | VAS (SD) [range] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Onlay glenoid TSA | | | | | | | | | | | |
| Walch et al (2012)[50] | 4 | 77 (14 to 180) | 92 | Asymmetric reaming with all-polyethylene glenoid (7 shoulder treated with PGBG) | | Pre: 32.4 (NR) [4 to 68] Post: 68.8 (NR) [25 to 95] | | | | | |
| Chin et al (2015)[6] | 3 | 60 (23 to 120) | 87 | Asymmetric reaming with pegged or keeled all-polyethylene glenoid | | | | Pre: 50 (NR) [NR] Post: 5 (NR) [NR] | | | |
| Steinmann and Cofield (2000)[47] | 4 | 60 (24 to 132) | 25 | TSA with PGBG<br>15 Metal-backed cemented glenoid<br>10 Metal-backed uncemented glenoid<br>3 All-polyehtylene glenoid | | | | | | | |
| Klika et al (2014)[29] | 4 | 105 (24 to 300) | 17 | TSA with PGBG<br>12 Metal-backed glenoid<br>6 All-polyehtylene keeled glenoid<br>7 All-polyethylene pegged glenoid | | | | | | | |
| Rice et al (2008)[42] | 4 | 60 (24 to 96) | 14 | TSA with wedged augmented all-polyetheylene glenoid | | | | | | | |
| Cil et al (2014)[7] | 4 | 88 (24 to 228) | 23 | TSA with polyehtylene or metal-backed augmented glenoid | Post: 55 (NR) [8-100] | | | | | | |
| RSA | | | | | | | | | | | |
| Collin et al (2019)[8] | 4 | 84 (60 to 192) | 49 | RSA (16 required bone grafting) | | Pre: 30 (NR) [NR] Post: 68 (NR) [NR] | | | | | |

*PROM*, patient-reported outcome measures; *LOE*, level of evidence; *ASES*, American Shoulder and Elbow Surgeons score; *SD*, standard deviation; *SST*, Simple Shoulder Test; *DASH*, Disability of the Arm, Shoulder, and Hand; *SANE*, Single Assessment Numeric Evaluation; *PSS*, Penn Shoulder Score; *VAS*, Visual Analog Scale; *TSA*, total shoulder arthroplasty; *PGBG*, posterior glenoid bone graft; *Pre*, preoperative; *NR*, not reported; *Post*, postoperative; *RSA*, reverse shoulder arthroplasty.

**Table III**
Summary of short-term ROM, complications, and radiographic findings.

| Author | Treatment | Forward flexion (range), in degree | External rotation, in degree | Abduction, in degree | Internal rotation, in degree | Complicatons | Radiographic results |
|---|---|---|---|---|---|---|---|
| Onlay glenoid TSA | | | | | | | |
| Gerber et al (2009)[14] | Asymmetric reaming | Improvement: 37 | | Improvement: 45 | | None reported | None reported |
| Alentorn-Geli et al (2018)[1] | Asymmetric reaming | Pre: 87.3 (NR)<br>Post: 164.9 (NR) | Pre: 9.6 (NR)<br>Post: 61.7 (NR) | | | 2 Asymptomatic glenoid loosening<br>2 Late rotator cuff insufficiency | 4 Posterior subluxation<br>9 Glenoids with lucency |
| Orvets et al (2018)[40] | Asymmetric reaming | | | | | 1 Symptomatic rotator cuff tear (revision) | 20 Glenoids with lucency |
| Sabesan et al (2013)[43] | All-polyethylene pegged or keeled glenoid with PGBG | Post: 156 (17) (110 to 170)<br>Improvement: 27.2 | Post: 49 (21) (30 to 90)<br>Improvement: 15.9 | | | 1 Infection (revision)<br>1 Glenoid mechanical failure (revision) | 2 Broken screws |
| Nicholson et al (2017)[37] | TSA with PGBG | Pre: 89<br>Post: 149 | Pre: 19<br>Post: 56 | | Pre: 28<br>Post: 47 | 1 Stiffness (reoperation) | 3 Broken screws<br>3 Broken central peg markers<br>2 Lucent lines (inferior peg) |
| Stephens et al (2017)[48] | TSA with augment | Pre: 109.5 (NR)<br>Post: 159.3 (NR) | Pre: 16.2 (NR)<br>Post: 48.1 (NR) | | | None | 5 Glenoids with lucency |
| Ho et al (2018)[22] | TSA with augment | Pre: 110 (60 to 170)<br>Post: 160 (90 to 180) | Pre: 20 (0 to 60)<br>Post: 50 (10 to 80) | | | None | 11 Glenoids with lucency<br>7 Humeral head subluxation |
| Priddy et al (2019)[41] | TSA with augment | Pre: 103 (NR)<br>Post: 141 (NR)<br>Improvement: 38.6 | Pre: 18 (NR)<br>Post: 48 (NR)<br>Improvement: 31.3 | Pre: 97 (NR)<br>Post: 134 (NR)<br>Improvement: 37.4 | Pre: 3.1 (NR)<br>Post: 5.3 (NR)<br>Improvement: 2.2 | 1 Infection (revision)<br>1 Glenoid loosening (revision) | 20 Glenoids with lucency |
| RSA | | | | | | | |
| Mizuno et al (2013)[35] | RSA | Pre: 89 (NR)<br>Post: 153 (NR) | Pre: 3 (NR)<br>Post: 27 (NR) | | Pre: Buttock (NR)<br>Post: T12 (NR) | 1 Early glenoid loosening (revision)<br>1 Transient axillary nerve palsy<br>1 Transient ulnar nerve palsy<br>1 Permanent ulnar nerve palsy | 10 Scapular notching<br>No other glenoid lucency noted |
| Harmsen et al (2017)[20] | BIO-RSA | Pre: 97.3 (NR)<br>Post: 138.6 (NR)<br>Improvement: 41.3 | Pre: 16.4 (NR)<br>Post: 32.8 (NR)<br>Improvement: 16.4 | Pre: 84.4 (NR)<br>Post: 130.9 (NR)<br>Improvement: 46.5 | Pre: buttock (NR)<br>Post: L3 (NR)<br>Improvement: 4 levels | 1 Early infection (antibiotics)<br>1 Late infection (revision) | 8 Scapular notching<br>3 Graft resorption |
| Alentorn-Geli et al (2018)[1] | RSA | Pre: 86.8 (NR)<br>Post: 160 (NR) | Pre: 10.0 (NR)<br>Post: 53.7 (NR) | | | None | None |
| Hemiarthroplasty | | | | | | | |
| Hsu et al (2016)[25] | Hemiarthroplasty with concentric glenoid reaming | | | | | 1 Infection (revision)<br>1 Stiffness (revision) | |
| Getz et al (2017)[15] | Hemiarthroplasty with concentric glenoid reaming | Post: 147.9 (110 to 180), only inlcuded patients no undergoing revision | Post: 39.4 (20 to 60), only inlcuded patients no undergoing revision | | | 4 Early revisions for continued pain and persistent stiffness<br>2 Long-term pain and stiffness (revision) | 4 Posterior humeral head subluxation |
| Inlay glenoid | | | | | | | |
| Cvetanovich et al (2019)[10] | Humeral head resurfacing with inlay glenoid | Pre: 107 (NR)<br>Post: 155 (NR) | Pre: 23 (NR)<br>Post: 55 (NR) | | | 1 Hematoma<br>1 Pulmonary embolism | No osteolysis, radiolucenct lines, or component change noted |
| Egger et al (2019)[11] | Humeral head resurfacing with inlay glanoid | Pre: 118.6<br>Post: 168.6 | Pre: 20.0<br>Post: 59.0 | | | None | 15 Incomplete lucency<br>9 Complete lucency |

*ROM*, range of motion; *TSA*, total shoulder arthroplasty; *Pre*, preoperative; *NR*, not reported; *Post*, postoperative; *PGBG*, posterior glenoid bone graft; *RSA*, reverse shoulder arthroplasty; *BIO-RSA*, bony increased offset-reverse shoulder arthroplasty.

**Table IV**
Summary of long-term ROM, complications, and radiographic findings.

| Author | Treatment | Forward flexion (range), in degree | External rotation (range), in degree | Abduction (range), in degree | Internal rotation (range), in degree | Complicatons | Radiographic results |
|---|---|---|---|---|---|---|---|
| Onlay glenoid TSA | | | | | | | |
| Walch et al (2012)[50] | Asymmetric reaming | Pre: 98.4 (30 to 165)<br>Post: 143.3 (60 to 180) | Pre: 7.0 (−40 to 60)<br>Post 37.3 (0 to 60) | | | 6 Glenoid loosening (revision)<br>5 Posterior dislocation (revision)<br>1 Capsulitis (reopreation)<br>1 Traumatic subscapularis tear (reoperation)<br>1 Persistent pain (reoperation)<br>1 Impingement (reoperation) | 26 Loosening (6 revised) |
| Chin et al (2015)[6] | Asymmetric reaming | Pre: 100 (NR)<br>Post: 150 (NR) | Pre: 25 (NR)<br>Post: 50 (NR) | Pre: 75 (NR)<br>Post: 110 (NR) | | 2 Infections (revision)<br>1 Failed subscapularis repair (revision)<br>1 Glenoid loosening (revision) | 18 Glenoids with lucency |
| Leschinger (2017)[31] | Asymmetric reaming | | | | | 2 Wound infection (no revision)<br>2 Temporary nerve palsy<br>1 Dislocation (no revision) | None noted |
| Steinmann and Cofield (2000)[47] | TSA wth PGBG | | Post: 39 (10 to 70)<br>Improvement: 27 | Post: 126 (80 to 180)<br>Improvement: 41 | Pre: L5<br>Post: T12 (sacrum to T 10)<br>Improvement: 5 levels | 2 Dislocation (reoperation) | 11 Incomplete lucency<br>4 Complete lucency (3 considered loose) |
| Klika et al (2014)[29] | TSA with PGBG | Post: 148 (80 to 180)<br>Improvement: 63 (−48 to 150) | Post: 60 (20 to 90)<br>Improvement: 39 (−35 to 120) | | Post: L1 (ileum to T9) | 2 Glenoid loosening (revision)<br>1 Persistent instability | 10 Glenoids at risk for railure.<br>Glenoid shifted in 6.<br>Bone graft resoprtion in 6 |
| Rice et al (2008)[42] | TSA with augment | | Pre: 35 (0 to 75)<br>Post: 56 (30 to 90) | Pre: 99 (45 to 150)<br>Post: 160 (120 to 180) | Pre: Sacrum<br>Post: L3 | None | 4 Humeral head subluxation<br>7 Glenoids with lucency<br>1 Glenoid shifted position |
| Cil et al (2014)[7] | TSA with augment | Pre: 91 (0 to 60)<br>Post: 126 (30 to 180) | Pre: 24 (−10 to 80)<br>Post: 53 (0 to 90) | | Pre: Scarum<br>Post: L2 | 2 Early infections (revision)<br>1 Early infection (antibiotics)<br>1 Glenoid component loosening (revision) RCR intraop<br>2 Early persistent subluxation (revision) Walch B2<br>2 Anterior instability (revision) Walch A<br>1 Humeral component loosening<br>1 Glenoid loosening | 6 Glenoids at risk for loosening (3 underwent revision)<br>11 Shoulders with moderate to severe subluxation (5 new onset) |

(*continued on next page*)

**Table IV** (*continued*)

| Author | Treatment | Forward flexion (range), in degree | External rotation (range), in degree | Abduction (range), in degree | Internal rotation (range), in degree | Complicatons | Radiographic results |
|---|---|---|---|---|---|---|---|
| | | | | | | and humeral ostelysis with fracture (revision)<br>1 Poly wear with severe glenoid osteolysis | |
| RSA | | | | | | | |
| Collin et al (2019)[8] | RSA | Pre: 89 (NR)<br>Post: 145 (NR) | Pre: 3 (NR)<br>Post: 18 (NR) | | Pre: 3.6 (NR)<br>Post: 6.5 (NR) | 2 Infection (revision)<br>1 Transient radial nerve palsy | 20 Scapular notching<br>2 Glenoid lucency |

*ROM*, range of motion; *Pre*, preoperative; *NR*, not reported; *post*, postoperative; *TSA*, total shoulder arthroplasty; *PGBG*, posterior glenoid bone graft; *intraop*, intraoperative; *RCR*, rotator cuff repair; *RSA*, reverse shoulder arthroplasty.

Two studies reported midterm follow-up at a mean 74 months in 37 shoulders. There were 3 (8.1%) glenoids revised for failure at 1.5, 8, and 8.1 years. Four shoulders (10.8%) were revised for instability at 2.7, 3.3, 24, and 88 months. Radiographically, 7 (18.9%) shoulders were at risk of failure of which 3 were revised. Fifteen (40.5%) shoulders had moderate to severe subluxation.[7,42]

### *Reverse shoulder arthroplasty*

A total of 4 studies were identified with 118 shoulders, with a mean follow-up of 51.75 months (range, 24-192), and a mean age of 73 years (range, 53-89).[1,20,35]

All 4 studies reported PROMs, with the Constant score reported in 2. The mean scores improved from 30.5 to 72.[8,35] Harmsen et al reported improved mean ASES scores (33.9 to 87.9) and mean Single Assessment Numeric Evaluation scores (29.5 to 89.0).[20] All patients in their series required PGBG.[20]

All 4 studies reported ROM. The mean FF improved from 90° to 149°. The mean ER improved from 8.1° to 32°.[1,8,20,35]

Three studies were considered short-term with a total of 69 shoulders. Revision due to glenoid failure was reported in 1 (1.4%) shoulder at 4 months.[35] Scapular notching was reported in 18 (26%).[1,20,35]

Collin et al reported midterm follow-up at a mean 84 months in 49 shoulders. There were no glenoid or humeral component failures, and no instability. They reported 20 glenoids (40.8%) with scapular notching, and 2 (8.2%) with underlying lucency.[8]

### *Hemiarthroplasty with concentric glenoid reaming (ream-and-run)*

Two studies with a total of 57 shoulders with mean age 55 years were identified.[15,25] Both studies reported PROMs, and SST was reported. Hsu et al reported improvement in SST score from 4.8 to 10.[25] Getz et al included those patients not undergoing revision in scoring and reported a postoperative SST score of 10.4.[15]

One study reported ROM and again did not include those patients undergoing revision in their analysis. The postoperative FF was 148°, and the postoperative ER was 39.4°.[15]

Getz et al reported that 4 of 24 (17%) patients had persistent posterior HH subluxation, but none required revision.[15] However, there were 6 (25%) revisions reported at a mean 14.5 months; 4 early revisions for persistent pain and stiffness and 2 for late pain and stiffness.[15] Hsu et al reported 2 (6%) total complications; 1 (3%) infection that required revision and 1 (3%) revision for pain and stiffness.[25]

### *Nonspherical humeral head arthroplasty with inlay glenoid*

There were 2 studies which included 36 shoulders. The average age was 55.5 years (range, 42-71) with a mean follow-up of 41.3 months (23-74).[10,11] These studies combined a novel nonspherical HH implant used with an inlay glenoid placed at or below the surrounding bone. No attempts were made to restore normal version or correcting bony deformity.

Two studies reported preoperative and postoperative scores for comparison. All outcomes demonstrated improvement, specifically the ASES improved from 39.5 to 85.7 in a study by Cvetanovich et al.[10] Egger et al recorded Penn Shoulder Score, and postoperative scores were double the preoperative scores (42.2 to 88.6).[11] Pooled VAS pain scores improved from 5.9 to 1.3.[10]

All studies reported ROM, and all measurements improved postoperatively. The FF improved from 112.8° to 161.8°, and ER improved from 21.5° to 57°.

Two studies reported short-term radiographic outcomes and complications. Incomplete lucencies were present in 15 (41%)

**Table V**
Short-term complication summary.

| Technique | Shoulders | Revisions | Subluxation | Loose/At risk | Other |
|---|---|---|---|---|---|
| Asymmetric reaming | 74 | 2 (3%)<br>*2 Glenoid loosening (3%)*<br>*1 Synptomatic rotator cuff tear (1.4%)* | 4 (5%) | 0 | 29 Lucency (39%) |
| PGBG | 37 | 3 (8.1%)<br>*1 Glenoid loosening (2.7%)*<br>*1 Stiffness (2.7%)*<br>*1 Infection (2.7%)* | 0 | 0 | 2 Lucency (5.4%)<br>5 Broken screws (13.5%)<br>3 Broken central peg markers (8.1%) |
| Augmented glenoid | 123 | 2 (1.6%)<br>*1 Glenoid loosening (0.8)*<br>*1 Infection (0.8%)* | 7 (5.7%) | 0 | 36 Lucency (29%) |
| RSA | 69 | *2 (3%)*<br>*1 Glenoid loosening (1.4%)*<br>*1 Infection (1.4%)* | 0 | 0 | 18 Notching (26%)<br>3 Graft resorption (4.3%) |
| Hemiarthroplasty with concentric reaming | 57 | 8 (14%)<br>*7 Stiffness and pain (12.3%)*<br>*1 Infection (1.75%)* | 4 (7%) | N/A | 0 |
| Humeral head replacement with inlay glenoid | 36 | 0 | 0 | 0 | 15 Incomplete lucency (41%)<br>9 Complete lucency (25%) |

*PGBG*, posterior glenoid bone grafting; *RSA*, reverse shoulder arthroplasty; *N/A*, not applicable.
Number listed in italics refers to number of shoulders involved.

**Table VI**
Long-term complication summary.

| Technique | Shoulders | Revisions | Subluxation | Loose/At risk | Other |
|---|---|---|---|---|---|
| Asymmetric reaming | 179 | 19 (10.6%)<br>7 Glenoid loosening (4%)<br>5 Instability (2.8%)<br>2 Subscapularis tear (1.1%)<br>2 Infection (1.1%)<br>1 Persistent pain (0.55%)<br>1 Impingement (0.55%)<br>1 Capsulitis (0.55%) | 0 | 26 (14.5%) | 18 Lucency (24%) |
| PGBG | 42 | 5 (12%)<br>2 Glenoid loosening (4.7%)<br>3 Instability (7.1%) | 0 | 19 (45%) | 15 Lucency (35.7%)<br>6 Bone graft resorption (14.3%) |
| Augmented glenoid | 37 | 10 (27%)<br>3 Glenoid failure (8.1%)<br>4 Instability (10.8%)<br>2 Infection (5.4%)<br>1 Humeral component loosening (2.7%) | 15 (40.5%) | 7 (18.9%) | 7 Lucency (18.9%) |
| RSA | 49 | 2 Infection (4.1%) | 0 | 0 | 20 Notching (41%)<br>2 Lucency (4.1%) |

*PGBG*, posterior glenoid bone grafting; *RSA*, reverse shoulder arthroplasty.

shoulders, and complete lucencies in 9 (25%) shoulders, with none of the glenoids loose, at risk, or migrated at a mean 41.3 months of follow-up. No subluxations, instability, progressive lucencies, or revisions were noted.[10,11]

## Discussion

Posterior glenoid erosion or excessive retroversion, with or without HH subluxation in the presence of osteoarthritis, poses a unique challenge to patients and surgeons and has been associated with increased complications and poor clinical outcomes.[27,50] Currently there is no consensus regarding the ideal technique, approach, or implant choice. The goal of this systematic review was to synthesize all the available literature regarding outcomes related to surgical techniques.

For the purpose of evaluation, we defined short-term studies as <5 years and midterm as >5 years. The included studies demonstrated significant improvement in PROMs and ROM in the short term and midterm. The most commonly used PROMs were ASES, Constant, and SST scores, as well as VAS. The improvement from preoperative to postoperative period was comparable between studies and techniques.[6-8,10,14,15,20,25,29,35,37,40,41,47,48,50] A similar finding was noted with ROM, with the most commonly measured motions being FF and ER.[6-8,10,15,20,22,29,35,37,41-43,48,50] From a clinical standpoint, each technique can lead to a significant improvement in the immediate short term.

In the short term, HACR had the highest revision rate (Table V). In the present review, Hsu et al and Getz et al demonstrated an improved SST score.[15,25] However, Getz et al included only patients not undergoing revision in the analysis.[15] The majority of revisions were due to persistent symptoms of pain and stiffness (14%).[15,25] The technique by Getz et al also yielded the largest percentage of posterior subluxated shoulders (17%) although none were revised.[15] Hsu et al modified their technique by using an anteriorly eccentric HH to correct posterior decentering.[25] This technique yielded promising results with no shoulders demonstrating subluxation at the final follow-up.[25] However, they did report 1 (3%) revision secondary to persistent pain.[25] Somerson et al reviewed HACR results in a population of heterogenous glenoids and found that preoperative glenoid morphology was significantly associated with change in SST, with type A having greater improvement than types

B1 or B2.[46] Results of HACR in the setting of posterior HH subluxation with or without posterior glenoid erosion appear to lead to inconsistent clinical results and should be approached with caution. All previous studies have only tested spherical designs. Recent studies suggest that a nonspherical HH is more anatomic and shows less stress on glenoid, which may improve the outcomes of HA.[21,26,31]

Glenoid component loosening is of ongoing concern for onlay designs. Short-term radiographic outcomes and complication rates varied between techniques (Table V). The most common short-term radiographic finding was lucency behind onlay glenoid components (39% AROG, 29% AG, 5.4% PGBG).[1,22,37,40,41,42,48] Scoring systems have been described for glenoid component lucency using both standard radiographs and CT scans; however, the natural history is unknown.[4,30] It is generally accepted that progression of radiolucency on serial imaging is concerning for loosening.[51] The findings are concerning to the survival of the implant, especially in AROG and AG where the degree of correction may be limited by preoperative retroversion. The AG is further limited by the augment design options available.[22,39] Midterm studies supported this concern as the onlay techniques also had the most cases of radiographic loosening (14.5% AROG, 45% PGBG, and 18.9% AG).[6,7,29,47,50] In one of the largest cohorts, Walch et al demonstrated an increased rate of glenoid loosening (20.6%) using AROG for TSA, of which 6 (6.5%) were revised at a mean 96 months.[50] Glenoid retroversion of 27° or more carried a 44% complication rate.[50] Steinmann and Cofield reported an increased rate of loosening (10.7%) in their cohort with PGBG at a mean 64 months.[47] Klika et al demonstrated similar results in patients undergoing PGBG at a mean 105 months of follow-up.[29] Ten shoulders had a glenoid that was at risk for failure (40%), with 2 undergoing revision (8%).[29] Posterior HH subluxation was noted in short-term (5.7% AG and 5% AROG) and long-term (40.5% AG) studies.[1,7,22,42] The onlay glenoid was the only technique that required revision due to instability (2.8% AROG at mean 30 months, 7.1% PGBG at mean 6.5 months, 10.8% AG at mean 28.5 months).[6,7,29,47,50] The glenoid component continues to be an area of concern in onlay glenoid techniques whether they be standard or augmented designs; furthermore, the limited constraint design poses a risk for long-term stability (Table VI).

Mizuno et al proposed expanding the indications of RSA to address the concerns associated with onlay TSA designs.[35] The combined short- and midterm radiographic results were promising in the included studies. No cases of subluxation were reported, and there were no documented failures due to instability.[1,8,20,35] Revisions due to glenoid loosening were equally low in the short term in both RSA and bony increased offset-RSA (1.4%) and occurred at less than 16 months.[1,5,34,35] Recently, Ho et al reported on a series of radiographic failures in patients undergoing RSA with bone grafting at a median of 8 months; however, the patient population was heterogenous including a variety of diagnoses, revision cases, and use of autograft and allograft.[24] Radiographic failure was documented in 11 of 44 shoulders (25%), and 3 of 11 failures underwent revision. A direct comparison to the present study is difficult due to their broad inclusion criteria.[24] Further evaluation is warranted given these findings. Midterm results of RSA appear to be promising. Collin et al reported no revisions due to glenoid loosening or instability at a mean 84 months of follow-up.[8] Screw fixation appears to provide short- and long-term benefits when compared to the standard onlay design. This is apparent in lower revision rates due to glenoid failure in RSA compared to other onlay techniques, as well as the significantly lower rate of lucency in the long term (Table VI). Furthermore, the constrained design of RSA components appears to prevent instability although component instability does occur with RSA. While RSA in patients without rotator cuff insufficiency offered improved function, there are still activity limitations in the long term. Furthermore, the mean age of patients undergoing RSA in this review was 72.5 years. This technique may not be ideal for younger and more active patients and likely should be considered in older patients or those with lower postoperative functional demands. The complication and revision rates were lowest overall in the RSA group across the short term and midterm.

HACR has been recommended for younger patients, active patients, and/or laborers, but as we have already discussed, early revision due to ongoing symptoms is of concern. Nonspherical humeral head arthroplasty demonstrated good clinical results in both the short and long term with patients returning to a high activity level.[10,19] In a recent study, Egger et al reported results of a nonspherical HH with inlay glenoid replacement on 24 patients with B glenoids with a mean follow-up period of 42.6 months.[11] They concluded that inlay glenoid demonstrated excellent clinical benefits.[11] Two studies reported on outcomes of HH arthroplasty with an inlay glenoid. Radiolucencies were noted (41% incomplete and 25% complete); however, there was no concern for loosening based on lack of symptom complaints. Further long-term studies are needed to evaluate for progression of lucency and/or loosening. Furthermore, no revisions were required in either study included. The short-term radiographic results did not demonstrate any subluxation or instability. In addition, recent imaging analysis of this technique demonstrated recentering of the glenohumeral joint which was maintained. This suggests that correction of version and dealing with the bone loss may not be necessary to recenter the joint. Instead, the technique allows the surgeon to place the inlay component without reaming to correct the version and has been described as "play it as it lies." Inlay glenoid techniques also demonstrate improved stability and complications rates compared to all other techniques. A previous biomechanical study favored inlay glenoid over more traditional TSA glenoid designs for both stability and loosening.[13,18] This is likely owed to the inset design of the glenoid which can decrease the risk of edge loading.[13] This technique offers promising and consistent results in cases of glenoid bone loss. These results were supported in a long-term study by Gunther et al who evaluated outcomes following inset glenoid placement in cases of severe glenoid bone loss.[19] Although this technique is similar to the inlay technique, there are differences. The HH was spherical, which has some biomechanical implications in that stresses are reduced, center of rotation is restored better, and glenoid stresses are less compared with a nonspherical implant.[26] In addition, Gunther and Tran describes an inset glenoid which can still be prominent and therefore act as an onlay implant.[19] They reported an improved mean ASES score (23 to 95) at a mean 8.7 years.[19] Further long-term follow-up is still needed.

There were several limitations to our study. First, this systematic review consisted a majority of level 4 evidence with varying sample sizes. Most studies included reported heterogenous data in terms of glenoid type; however, a majority of them were glenoid type B, more specifically B2. Although the heterogeneity can skew the data, we felt that the manner in which the results were reported warranted inclusion. There was heterogeneity in PROMs, which is due to lack of standardized reporting. Lastly, long-term studies were lacking for every technique. Certainly, long-term outcomes will be important in helping guide recommendations for individual patients.

## Conclusion

Posterior HH subluxation and eccentric glenoid wear in arthritic shoulders remains a challenging problem. A variety of management strategies exist. Previous studies have reported increased risk of complications when the glenoid is implanted in greater than 15° of retroversion; thus, there are limits to standard TSA in the type B glenoids[23,39] without addressing the bone loss and posterior subluxation. AROG can reliably correct up to 10° of retroversion, and with greater degrees of retroversion, glenoid loosening is a serious concern.[16,39,50] Nowak et al have recommended that if there is a need for >15° of correction, the surgeon should consider techniques other than eccentric reaming alone.[39,45] In cases of significant bone loss or retroversion, deformity correction can be considered with either PGBG or AG componentsl; however, the long-term results of PGBG appear to be inconsistent. TSA with AG are concerning for eventual loosening and subluxation and will need to be followed for a long term. RSA offers promising short-term and midterm results likely due to the advantage of more secure fixation as well as a constrained design to prevent posterior subluxation. The mean age of patients undergoing RSA included in this review was 72.5 years, and based on activity limitations, this design is not ideal for younger or higher demand patients. HACR remain a viable option for younger patients; however, there is concern regarding long-term outcomes and risk of revision in more severe GHOA. Humeral head resurfacing arthroplasty and inlay glenoid have demonstrated favorable outcomes in this subset of patients, with the potential to return to high level of activities. The recently documented success of humeral head resurfacing arthroplasty with glenoid inlay construct provides some optimism for a simple solution to a difficult reconstructive option.

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## Supplementary data

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