JSES Reviews, Reports, and Techniques 5 (2025) 203–215

Contents lists available at ScienceDirect

JSES Reviews, Reports, and Techniques

journal homepage: www.jsesreviewsreportstech.org

Stemless reverse total shoulder arthroplasty: a systematic review and meta-analysis

Andrew Kelly, MB, BCh, BAO[a,*], Conor McNamee, MB, BCh, BAO[a,b], Thomas Deane, MB, BCh, BAO[a], James G. Kelly, MB, BCh, BAO[a,c], David Kelly, BSc[b], William Blakeney, MBBS, MS, MSc, FRACS[c]

[a]*Department of Surgery, National University of Ireland, Galway, Ireland*
[b]*School of Medicine, University College Dublin, Dublin, Ireland*
[c]*Department of Surgery, Royal Perth Hospital, Perth, Australia*

ARTICLE INFO

Keywords:
Reverse total shoulder arthroplasty
Stemless implant
Systematic review
Meta-analysis
Complications
Functional outcomes

Level of evidence: Level IV; Systematic Review and Meta-Analysis

Background: Stemless reverse total shoulder arthroplasty (rTSA) is one of the many modifications of the original Grammont rTSA design. Much has been made of the debate between stemless and stemmed humeral implants for anatomic reverse shoulder arthroplasty, with less attention awarded to the relatively newer variation in stemless rTSA. Proposed advantages of said design include preserving bone stock, ease of revision, reduced blood loss, and shortening surgical times.
Methods: A systematic search was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines using search engines in PubMed, EMBASE, and Cochrane to retrieve all relevant studies.
Results: Initial search strategies produced 174 studies, of which 15 studies were included for full analysis in this review. This included 657 shoulders in 648 patients (9 bilateral cases). Stemless rTSA led to significant improvement in functional outcomes and range of motion (ROM) across all studies. Meta-analysis of comparative studies including stemless and stemmed rTSA showed no significant difference in ROM measurements across abduction (standardized mean difference [SMD] −0.17, 95% confidence interval [CI]: −1.05, 0.70) or forward flexion (SMD -0.36, 95% CI: −1.23, 0.50). However, there was a statistically significant difference in internal rotation in favor of stemless implants (SMD -0.79, 95% CI: −1.56, −0.03). There was no significant difference in visual analog scale (VAS) between stemmed and stemless designs (SMD −0.31, 95% CI: −2.32, 1.69). Likewise, there was no significant difference in odds ratio (OR) for revision rates (OR: 1.02, 95% CI: 0.92, 1.14) or overall complications (OR: 0.82, 95% CI: 0.2, 3.42). Across all 15 studies, comparative and noncomparative studies, overall complication rates for stemless rTSA stood at 13.4% and revision rates at 5.5%.
Conclusion: Stemless rTSA achieves similar functional outcomes to stemmed rTSA designs. Stemless designs achieved superior internal rotation in the comparative studies. Proposed advantages of stemless rTSA including reduced blood loss and lesser surgical times need further research, as does the long-term robustness of this relatively novel design.

Reverse total shoulder arthroplasty (rTSA) was first successfully introduced by Paul Grammont in 1985, primarily as a treatment for rotator cuff tear arthropathy in the elderly.[23] His idea provided a more medialized glenohumeral center of rotation thus elongating and restoring tension to deltoid muscle which offloads the physical requirements of the impaired rotator cuff muscles. Since its inception, the surgical indications have expanded broadly, to now include treatment of primary osteoarthritis with or without rotator cuff arthropathy, proximal humeral fractures, reconstruction following tumor removal as well as revision of previously failed anatomic TSA. The design itself has also evolved since Grammont's initial design to help address issues such as aseptic glenoid loosening, scapular notching, and weakening of the remaining rotator cuff muscles.[32] Such design modifications include glenoid

Institutional review board was not applicable to this systematic review and meta-analysis.

*Corresponding author: Andrew Kelly, MB, BCh, BAO, Department of Surgery, School of Medicine, University of Galway, University Road, Galway, Ireland.
E-mail address: a.kelly176@universityofgalway.ie (A. Kelly).

https://doi.org/10.1016/j.xrrt.2025.01.003

lateralization, onlay systems, varying neck shaft angle (NSA), and stemless prostheses.[23,32]

Stemless anatomic total shoulder implant models were first brought to market at the turn of the century and have seen early successes in Europe and the United States.[10,26,38,45,46] Some of the proposed advantages of a stemless design are preserved bone stock with less reliance on humeral diaphysis for alignment and fixation, fewer periprosthetic fractures, reduced proximal humeral stress shielding, easier stem revision, lesser blood loss, simplification of revision surgery, and shorter overall surgical times—all of which are of significance in the elderly cohort.[5,7,27,38] Stemless anatomic TSA is a well-adopted approach in the orthopedic community with a large body of evidence to support its use.[2,27,40,45] Stemless rTSA designs have been available in European markets since 2005, but their use has been limited to clinical trials in the United States until recently. To date, there have been few high-quality studies synthesizing the stemless rTSA literature relating to clinical and functional outcomes. The authors of this study propose to systematically explore, review, and collate the literature surrounding stemless rTSA.

Methods

A search was performed on EMBASE, PubMed, and MEDLINE on 06/03/2024, without a date restriction, using keywords ((REVERSE SHOULDER ARTHROPLASTY) OR (REVERSE TOTAL SHOULDER ARTHROPLASTY) OR (REVERSE SHOULDER REPLACEMENT)) AND ((STEMLESS) OR (UNSTEMMED)).

The inclusion criteria were as follows: (1) studies with a minimum patient follow-up of 12 months, (2) at least one measured functional score, and (3) studies on humans. Exclusion criteria were (1) simulation studies/cadaver studies/animal studies; (2) level V studies, excluding case reports, expert opinion, and review articles; and (3) studies not reported in English.

Study selection

This systematic review and meta-analysis adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines. Two independent reviewers, A.K. and J.K., screened titles and abstracts of all studies identified from the initial search criteria. Any duplicates were identified and removed. Disagreements at the title and abstract stage were resolved by a third reviewer, T.D.

Data collection

The independent reviewers A.K. and J.K. reviewed the studies passing the initial extraction phase, in detail. The studies were analyzed to ensure they met inclusion and exclusion criteria with further omissions made accordingly in particular where studies had incomplete datasets.

Once a study was deemed to fulfill these criteria, data were collected using Google Sheets pertaining to study characteristics and comparisons headings. Study-specific data collected included patient demographic information, indications for surgery, surgical implant type, presurgical functional assessment, postsurgical outcomes (functional scores and ROM), radiological outcomes, and complications (revisions, infection, loosening, etc.).

Quality assessment

A.K. and J.K. independently performed quality assessment using the ROBINS-I tool[37] for observational studies. Disagreements were settled by consensus between the two authors. Studies were assigned a risk of bias (ROB) of low, intermediate, or high.

Statistical analysis and meta-analysis

Any functional outcome, clinical outcome, or complication that was reported three or more times in the comparative studies (stemless vs. stemmed) was meta-analyzed. Using R and meta package, a random effects model using the Mantel-Haenszel[36] method for rare events was used to assess the odds ratio (OR) of binary outcomes. When used for binary events, a conventional inverse variance weighted meta-analysis involves a normal approximation of the binomial likelihood which may fail where event rates are low. While there is no universally accepted definition of rarity, it was felt most adverse events after shoulder arthroplasty are relatively uncommon and therefore the Mantel-Haenszel method was chosen per Cochrane advice. In the event that events are common, the Mantel-Haenszel method produces results equivalent to inverse variance methods. For continuous data, a random effects model as described by DerSimonian and Laird[9] was used to assess the mean difference (MD) or OR between stemless and stemmed outcomes at the final measurement. Where continuous outcomes were measured across studies via different scales, standardized mean difference (SMD) with Hedge's g adjustment[43] was chosen as the effect size measure to facilitate the pooling of results. All confidence intervals were calculated including the Hartung-Knapp adjustment.[17] Random effects models were chosen a priori. In forest plots, standardized mean difference is abbreviated to SMD and confidence intervals are abbreviated to CI. Horizontal lines represent 95% CI of reported values. The solid squares represent SMD or OR between study arms and are proportional in size to the weights calculated for meta-analysis. The diamond shows the pooled SMD with the lateral tips of the diamond showing the associated 95% CI.

Inter-rater agreement

A kappa (κ) statistic indicating inter-reviewer agreement was calculated for all screening stages and pooled accordingly; 0.81-0.99 as excellent agreement, 0.61-0.80 as substantial agreement, 0.41-0.60 as moderate agreement, 0.21-0.4 as fair agreement, and 0.20 or less as slight agreement.

Results

Initial search results using an electronic database yielded 174 studies, of which 62 were deemed duplicates by initial screening (A.K.). Of the remaining 112 studies, 30 were considered for inclusion by authors A.K. and J.K., with 3 studies of conflict. The conflicts were resolved with input from third reviewer T.D. Thirty studies were fully reviewed and analyzed according to the inclusion and exclusion criteria. Fifteen studies met these criteria and were included in the systematic review.[1,3,4,6,8,13,20,25,29,30,31,33,39,44,42] There was excellent agreement between reviews at title and abstract (κ= 0.82) and substantial agreement at full text ($\kappa = 0.75$) review stage. A PRISMA flow diagram (Fig. 1) summarizes the selection process of this study. One study was level II evidence.[20] Four studies were level III evidence.[1,3,13,29] The remaining 10 studies were level IV evidence.[4,6,8,25,30,31,33,39,42,44]

Risk of bias

All 15 studies were subjected to ROB assessment using the Robins-I tool,[37] with 14 studies rated as having serious ROB. The

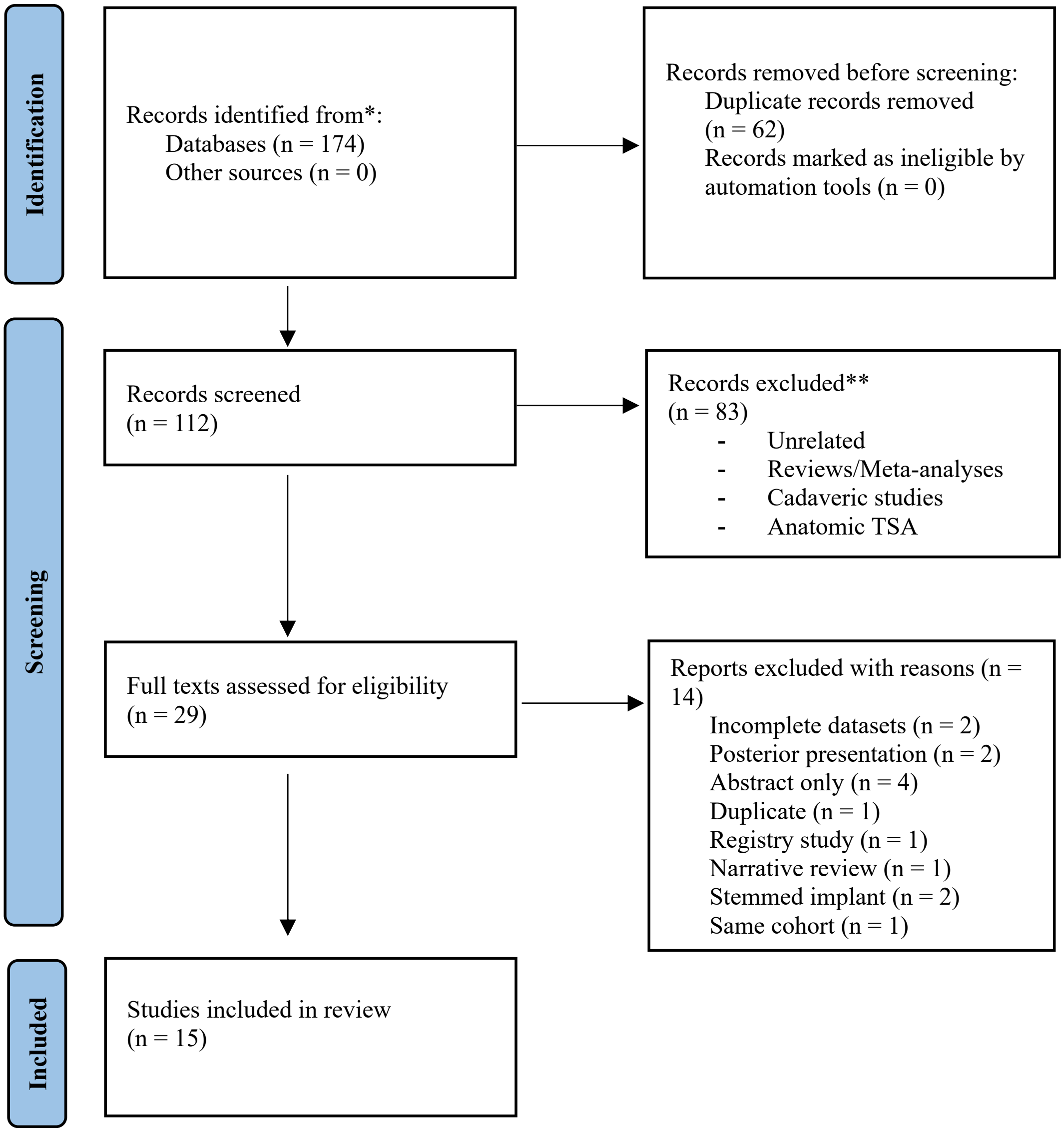

Figure 1 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart. *TSA*, total shoulder arthroplasty.

study by Kadum et al[20] was the exception to this, showing moderate ROB. The table (Fig. 2) below summarizes these findings.

Demographics

There were 657 shoulders operated on with stemless reverse shoulder arthroplasty implants in 648 patients (9 bilateral cases). The weighted mean age of included patients was 70.0 (range, 39-95). The male-to-female ratio was 1:1.7. The mean follow-up time was 45 months. The included studies ranged from 2013 to 2024 at the year of publication. There were 13 studies from Europe, one from India, and one from New Zealand. Three of the fifteen studies were comparative studies including matched stemmed and stemless rTSA groups. The remaining 12 were stemless implant-only studies. Study characteristics and demographic information can be seen summarized below in (Table I)

Implant design

In five studies, the *TESS* stemless prosthesis (Zimmer Biomet, Warsaw, IN, USA) was used.[4,6,20,29,39] This amounted to 216 shoulders or 32.8% of overall shoulders across all studies. The *SMR* stemless prosthesis (Lima Corporate S.p.A, Udine, Italy) was used in four studies,[1,31,33,44] in a total of 120 shoulders (18.3%). The *Verso* stemless prosthesis (Biomet, Swindon) was used in three studies,[8,25,42] in 101 shoulders (15.3%). The *Easytech* FX stemless prosthesis (FX Solutions, Dallas, TX, USA) was used in two studies,[3,30] in 205 shoulders (31.2%). The Comprehensive *Nano* stemless prosthesis (Zimmer Biomet, Warsaw, IN, USA) was used in one study,[13] in 15 shoulders (2.3%).

With regard to the specific design characteristics of each implant, the following can be said: The *TESS* prosthesis consists of a short reverse corolla uncemented metaphyseal-epiphyseal inlay CoCr implant, intended for 150-155 degree NSA placement. The *SMR* design is a trabecular Ti humeral core implant with a proximal ring and two radiating fins to central peg which is implanted directly into the metaphysis at an anatomic 135 degree NSA. The *Verso* design consists of a humeral implant with three hydroxyapatite-coated tapered fins for noncemented press-fit fixation intended for 155 degree NSA placement. The *Easytech* design involves an anchor base plate for peripheral fixation with the cortical rim. It has peripheral pegs with plasma-sprayed Ti and hydroxyapatite coating

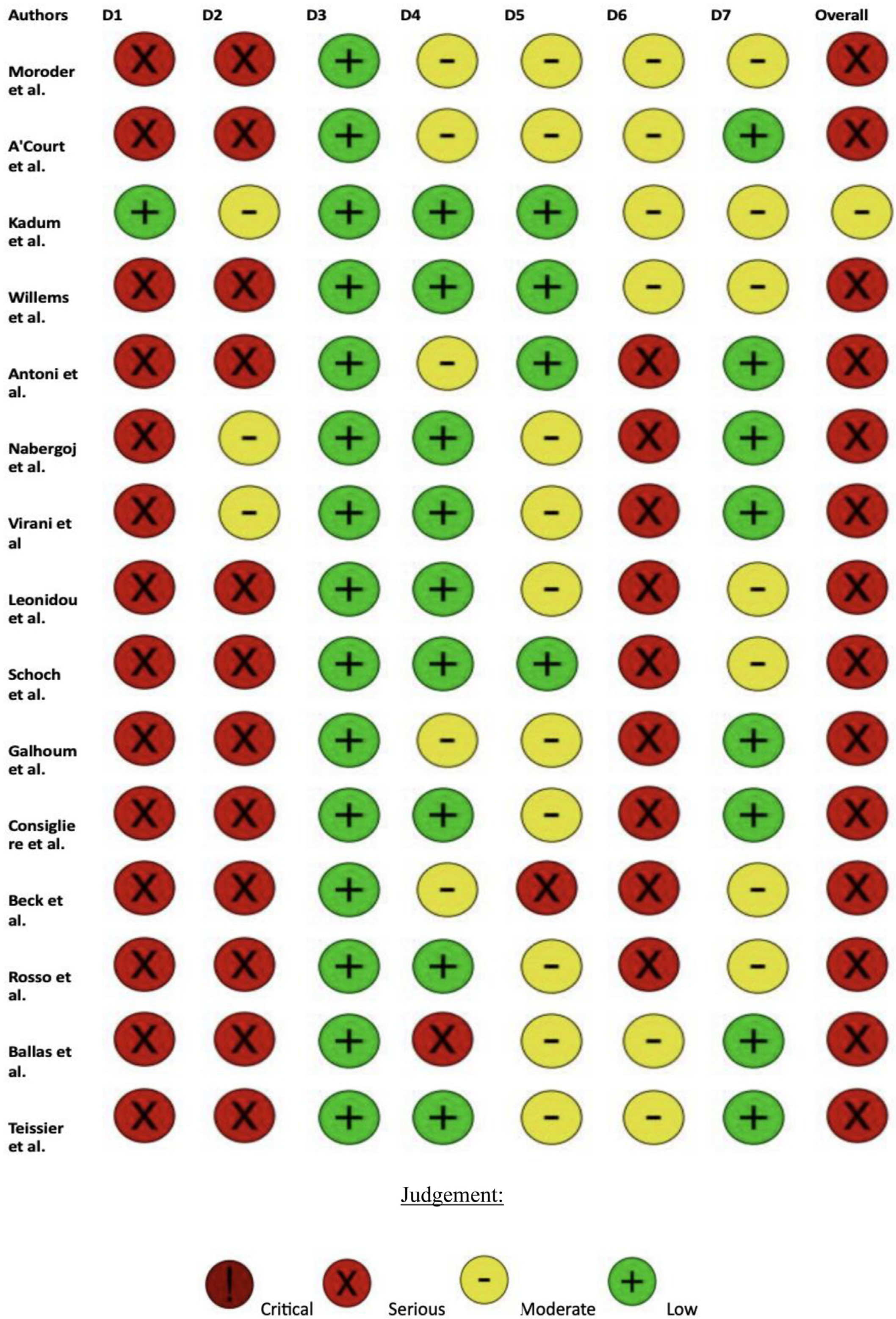

Figure 2 Robins-I assessment traffic light plot: D1, Bias due to confounding; D2, Bias due to selection of participants; D3, Bias in classification of interventions; D4, Bias due to deviations from intended interventions; D5, Bias due to missing data; D6, Bias in measurement of outcomes; D7, Bias in selection of the reported result.

to support the onlay design with a 145 degree NSA placement design. The comprehensive *Nano* system has an onlay tray design that has had to undergo numerous design modifications, with manufacturers currently reviewing its usage for rTSA.[28]

Indications

Indications for surgery with a stemless reverse implant were variable. The most common being rotator cuff dysfunction and cuff

Table I
Study characteristics and demographics of stemless rTSA studies.

Authors	Country	Journal	Year of publication	Study design	Indications	Level of evidence	Comparison study (1) or stemless only(0)	Implant type	Patient shoulders, n	Mean follow-up, mo	Mean age	Age range	Sex m/f
Moroder et al[29]	Germany	*International orthopaedics*	2020	Retrospective comparative	CTA	3	1	TESS	24	24	75	71-79	7/17
A'Court et al[1]	New Zealand	*JSES*	2024	Retrospective comparative	OA, RA, CTA	3	1	SMR	30	37.5	69	53-84	6/18
Kadum et al[20]	Germany	*International orthopaedics*	2014	Prospective comparative	CTA, OA, rotator cuff dysfunction, fracture sequelae	2	1	TESS	16	39	72	60-88	6/10
Willems et al[44]	Netherlands	*JSES*	2024	Prospective comparative	OA, inflammatory arthritis, CTA	4	0	SMR	12	24	78.3	74-82	9/6
Antoni et al[3]	France	*JSES*	2024	Retrospective cohort	OA, CTA, trauma sequelae	3	0	Easytech	90	31.2	65.8	56-74	48/42
Nabergoj et al[30]	France	*JSES*	2023	Prospective cohort	CTA	4	0	Easytech	115	24	68	60-76	54/61
Virani et al[42]	India	*Journal of clinical orthopaedics and trauma*	2021	Prospective case series	CTA, RA, revision, trauma	4	0	Verso	20	78	76	67-95	
Leonidou et al[25]	France	*European journal of orthopaedic surgery & traumatology*	2020	Prospective case series	CTA, RA, revision, trauma	4	0	Verso	37	36	76.9	-	9/27
Schoch et al[33]	Germany	*JSES*	2021	Prospective case series	CTA, OA	4	0	SMR	52	29.3	61.2	46-76	-
Galhoum et al[13]	UK	*JSES*	2022	Prospective comparative	CTA, OA, revision, RA	3	0	Nano	15	40.4	-	-	-
Consigliere et al[8]	UK	*Musculoskeletal surgery*	2021	Prospective cohort	RA	4	0	Verso	44	57	68.7	39-86	9/27
Beck et al[6]	Germany	*Archives of Orthopaedics and Trauma Surg.*	2019	Retrospective cohort	CTA, fracture sequelae, revision arthropathy	4	0	TESS	29	101.6	72.4	53-88	5/22
Rosso et al[31]	Switzerland	*JSES*	2023	Retrospective case series	CTA, OA	4	0	SMR	26	46.8	70.1	59.9-86.4	
Ballas et al[4]	France	*JSES*	2013	Prospective case series	CTA, OA	4	0	TESS	56	59	74	55-85	16/40
Teissier et al[39]	France	*JSES*	2015	Prospective cohort	CTA	4	0	TESS	91	41	73	55-89	61/26

OA, osteoarthritis; *RA*, rheumatoid arthritis; *CTA*, cuff tear arthropathy; *n*, number of patients; *sex m/f*, male to female ratio; *JSES*, *Journal of Shoulder and Elbow Surgery; rTSA*, reverse total shoulder arthroplasty.

tear arthropathy. Other indications include osteoarthritis, rheumatoid arthritis, proximal humeral fracture sequelae, and revision surgery for previous shoulder arthroplasty.

Patient-reported outcome measures and functional scores

The patient-reported outcome measures (PROMs) and functional scores used were highly variable across studies which makes direct comparison challenging. However, in each individual study, there was a statistically significant improvement in functional scores from preoperative to postoperative when a reverse stemless shoulder prosthesis was used. The absolute Constant score (CS) was the most commonly measured functional score, used in 12 studies.[3,6,4,8,13,29,30,31,33,39,42,44] Of these, 11 studies (541 patients) measured preoperative and postoperative CS with a mean weighted improvement of 33.7 or 106.6% improvement from a weighted mean preoperative CS of 31.6. Weighted mean postoperative CS was 65.4. American Shoulder and Elbow Surgeons (ASES) score was measured in seven studies totaling 233 patients.[1,3,13,30,29,31,44] Of these, four[13,30,31,44] measured preoperative and postoperative ASES scores. The weighted mean improvement of ASES score across these five studies was 41.5 or 111.9% from a weighted mean preoperative ASES score of 37.1. Weighted mean postoperative ASES score was 78.6. QuickDASH score was measured in five studies[6,20,31,39] totaling 275 patients. Of these, four studies measured preoperative and postoperative QuickDASH scores for comparison. The weighted mean improvement in QuickDASH score (lower values are improvements) was 33 or 56.6% from a weighted mean preoperative score of 58.3. The weighted mean postoperative score was 24.7. Other functional outcome scores and PROMs recorded across all studies were Subjective Shoulder Value, EuroQol-5D, Oxford Shoulder Score, ADLIER score, Single Assessment Numeric Evaluation score, University of California Shoulder Score, and simple Visual Analog Scales (VAS).

In the comparison studies involving stemmed and stemless implants, complete preoperative and postoperative functional data sheets for stemmed implants were recorded by only Kadum et al for QuickDASH scores showing a mean improvement of 21 or 37.5%. Complete, postoperative-only, data sets were available for VAS in the three comparative studies.[1,20,29]

Range of motion

Range of motion (ROM) outcomes were measured by 14 of the 15 studies. The study by Antoni et al[3] being the exception, choosing to focus on functional scores alone. Stemless rTSA resulted in significant improvement in all measured ROMs for each study ($P < .05$). Forward flexion (FF) was the most commonly recorded ROM with preoperative and postoperative scores available for 446 patients across 10 studies.[4,6,8,13,20,30,31,33,39,44] The mean weighted improvement in FF was 51.6. Preoperative and postoperative abduction (AB) was measured in seven studies[6,8,13,20,30,33,39] with a weighted mean improvement of 47 degrees. Preoperative and postoperative external rotation with elbow at 0 degrees AB was measured in seven studies[4,8,13,31,33,39,44] including 288 patients resulting in a mean weighted improvement of 18.8 degrees. Five studies[8,20,29,31,39] measured internal rotation (IR); however, direct comparison of all was not possible given differences in metrics used (CS score, degrees, vertebral landmarks). A summary of ROM measurements can be seen in (Table II).

Complications

When considering complications for analysis, the authors excluded radiological complications such as notching and focused on clinical complications. Reference to complications was made in all 15 studies. Across the 648 patients who underwent stemless rTSA, there were a total of 87 complications (13.4%). Overall revision rates were found to be 5.5%. Implant loosening occurred in 3.1%. Implant dislocation occurred in 1.2%. Postoperative infection occurred at a similar rate of 1.2%. Periprosthetic fractures were often recorded but it was not always specified whether they were traumatic or atraumatic. The overall rate of periprosthetic fractures was 2.2%. Intraoperative humeral fractures occurred in 0.9 % of cases. Complications not listed above can be seen in the table below (Table III). Scapular notching was inconsistently reported across studies with many authors not specifying notching as per grading systems. The overall rate of scapular notching was 18.5% with the majority of specified cases being low grade (1/2) as per the Nerot-Sirveaux classification. A summary of complications from included stemless rTSA studies can be seen in (Table III).

Stemless vs. stemmed rTSA comparative studies

There were three studies directly comparing stemless and stemmed rTSA implants.[29,1,20] Moroder et al offered postoperative CS, ASES, Subjective Shoulder Value, and VAS scores for the comparative groups. They noted no significant difference between stemless and stemmed rTSA groups for functional outcomes or in patient satisfaction scores. The authors measured surgical times and noted an average implant time of 80.5 minutes in the stemless group and 109.5 minutes in the stemmed group ($P < .001$). They found average hospital stay was significantly longer in the stemless rTSA group (11.8 vs. 7.9 days $P = .006$). Out of the two matched 24 patient groups, two of the patients from the stemmed group required a postoperative blood transfusion compared to zero in the stemless group, which was not found to be statistically significant ($P = .180$).

A'Court et al did not find any statistically significant difference in stemmed vs. stemless implant groups for PROMs including ASES, Oxford Shoulder Score, and satisfaction scores. They found comparable postoperative ROMs with no statistically significant difference across FF, AB, external rotation, or IR. Similarly, they found no significant difference in overall postoperative complications.

Kadum et al found no statistically significant difference between improvements in ROM across AB, FF, and IR in stemmed vs. stemless groups. They also reported no significant difference in PROMs and clinical scores including Quick Disabilities of Arm, Shoulder and Hand (DASH), EuroQol-5D, and VAS.

Meta-analysis of comparative studies

Across the three comparative studies, there were complete data sets amenable to meta-analysis for ROM parameters: AB, FF, IR; visual analog scale (VAS); revision rates; and overall complications.

Postoperative ROM comparisons are as follows: There was no statistically significant difference for AB (SMD -0.17, 95% CI: −1.05, 0.70) (Fig. 3). There was no statistical significance for FF (SMD −0.36, 95% CI: −1.23, 0.50) (Fig. 4). There was statistical significance for IR favoring stemless over stemmed (SMD −0.79, 95% CI: −1.56, −0.03) (Fig. 5).

When comparing PROMs, meta-analysis revealed no difference in VAS between stemmed and stemless rTSA cohorts (SMD −0.31, 95% CI: −2.32, 1.69) (Fig. 6).

Lastly, when comparing stemmed and stemless rTSA cohorts on the basis of revision rates and overall complications, there was no

Table II
Range of motion (ROM) measurements for stemless rTSA cases preoperatively to postoperatively with calculated improvements.

Authors	Pts, n	Time of measurement	Flexion	Abduction	External rotation at 0 degrees	Internal rotation
A'Court et al[1]	**30**	**Preop**	-	-	-	-
		Postop	117 ± 24	105 ± 30	31 ± 17	-
		change	**-**	**-**	**-**	**-**
Willems et al[44]	**12**	**Preop**	71 ± 38	-	26 ± 20	-
		Postop	116 ± 34	-	30 ± 23	-
		change	**45**	**-**	**4**	-
Nabergoj et al[30]	**115**	**Preop**	107 ± 35	93 ± 33	-	-
		Postop	136 ± 22	117 ± 27	-	-
		change	**29**	**24**	**-**	**-**
Virani et al[42]	**21**	**Preop**	-	-	-	-
		Postop	136	112	47	-
		change	**-**	**-**	**-**	**-**
Leonidou et al[25]	**37**	**Preop**	-	-	-	-
		Postop	133	110	30	-
		change	**-**	**-**	**-**	**-**
Schoch et al[33]	**52**	**Preop**	72 ± 23	87 ± 25	15 ± 17	-
		Postop	130 ± 18	138 ± 25	28 ± 10	-
		change	**58**	**51**	**13**	**-**
Galhoum et al[13]	**15**	**Preop**	82 ± 43	77 ± 35	15 ± 15	-
		Postop	110 ± 36	100 ± 33	45 ± 25	-
		change	**18**	**23**	**30**	**-**
Consigliere et al[8]	**36**	**Preop**	59	52	10	25
		Postop	140	134	47	70
		change	**81**	**82**	**37**	**45**
Beck et al[6]	**27**	**Preop**	52 ± 14	38 ± 10	-	-
		Postop	136 ± 27	116 ± 27	-	-
		change	**84**	**78**	**-**	**-**
Rosso et al[31]	**26**	**Preop**	66 ± 54	-	28 ± 20	L2
		Postop	155 ± 23	-	26 ± 11	L3
		change	**89**	**-**	**−2**	**L2-L3**
Moroder et al[29]	**24**	**Preop**	-	-	-	-
		Postop	8 (points)	7	-	5
		change	**-**	**-**	**-**	**-**
Ballas et al[4]	**56**	**Preop**	79 ± 28	-	13 ± 22	-
		Postop	140 ± 17	-	45 ± 15	-
		change	**61**	**-**	**32**	**-**
Teissier et al[39]	**91**	**Preop**	96 ± 0	89 ± 28	26 ± 25	L3
		Postop	143 ± 42	138 ± 49	39 ± 3	L4
		change	**47**	**49**	**13**	**L3-L4**
Kadum et al[20]	**16**	**Preop**	50	30	-	sacrum
		Postop	110	110	-	L3
		change	**60**	**80**	**-**	**L3-sacrum**

rTSA, reverse total shoulder arthroplasty.
Bold highlights change scores.

significant difference in OR for either outcome. Revision rates (OR: 1.02, 95% CI: 0.92, 1.14) (Fig. 7). Overall complication rates (OR: 0.82, 95% CI: 0.2, 3.42) (Fig. 8).

Implant design comparison

When comparing the five implant designs across all included stemless rTSA studies, *Verso*, *TESS*, *SMR*, *Nano*, and *Easytech*, weighted mean complication rates were as follows: *Verso*: 17.9%, *TESS:* 9.9%, *SMR:* 19.4%, *Nano:* 20%, and *Easytech:* 11.6%. As mentioned above, complications included for comparison were strictly clinical and did not include radiological complications. In situations where a complication led to a revision surgery, this was counted as one complication only. The findings of the complication rates by implant type are summarized below in (Table IV).

Discussion

This review included all published studies relating to stemless rTSA within the selection criteria. It found significant improvements in ROM and functional outcome scores when comparing preoperative and postoperative measurements. This is not unique to stemless rTSA and is a shared finding in pooled analyses of rTSA regardless of implant used (stemless or stemmed).[1,12,14,20,29,45]

There have been previous systematic reviews relating to stemless rTSA,[2,18,22,27] but to our knowledge, this is the first meta-analysis of results from studies comparing clinical outcomes of stemless and stemmed rTSA. The addition of a meta-analysis to the existing literature allows for objective appraisal of evidence and has helped to expose differences in clinical outcomes when comparing treatment options, in particular in relation to the improvements in IR in stemless vs. stemmed rTSA. Previous systematic reviews such as that by Liu et al[2] offer hypothetical advantages of stemless over stemmed rTSA including preservation of bone stock, reduced surgical time, and ease of revision but fail to offer any statistically significant definitive advantages of one option over the other. Other existing systematic reviews on the subject matter by Ajibade et al[2] and Kostretzis et al[22] quote comparison figures from discrete stemmed rTSA systematic reviews to evaluate their results. This review evaluates quantitatively the clinical outcomes and complication rates observed in direct comparison studies where other systematic reviews have failed to do so. Our meta-analysis revealed no statistically significant difference in ROM outcomes for AB (SMD −0.17, 95% CI: −1.05, 0.70) or FF (SMD −0.36, 95% CI: −1.23,

Table III
Complication overview for stemless rTSA cases.

Authors	n, pts (stemless only)	Scapular notch	Average hospital stay, d	Revision	Dislocation	Infection	Periprosthetic fracture	Loosening	Overall complications	Specific complications (if not listed)
Moroder et al[29]	24	1	11.8	1	1	-	-	-	3	Acromial spine fracture (1), symptomatic mesoacromion
A'Court et al[1]	30	-	-	3	-	2	1	2	7	Supranuclear palsy, intraop humeral fracture (2)
Kadum et al[20]	16	4	-	2	-	-	-	2	2	
Willems et al[44]	12	0	-	2	-	-	-	2	2	
Antoni at al.[3]	90	28	-	3	-	1	3	-	5	
Nabergoj et al[30]	115	28	-	8	3		1	9	18	Humeral implant displacement
Virani et al[42]	21	5	-	1	0	0	2	0	3	
Leonidou et al[25]	37	7	-	3	0	1	2	1	14	
Schoch et al[33]	52		-	2	0	1	1	1	5	
Galhoum at al.[13]	15	0	-	1	0	0	0	2	3	
Consigliere et al[8]	36	0	-	1	1	-	3	0	7	Intraop humeral fracture (3)
Beck et al[6]	27	21	-	3	2	1	-		4	
Rosso et al[31]	26	4	-	1	0	0	0	0	9	Dysesthesia of hand, hematoma, biceps tendon tear
Ballas et al[4]	56	5	-	4	-	1	1	0	9	Intraop humeral fracture (1), hematoma req evacuation, subscapularis rupture
Teissier et al[39]	91	17	-	1	1	0	0	0	3	Stress fracture of scapula, traumatic clavicle fracture

n, number of patients; *rTSA*, reverse total shoulder arthroplasty.

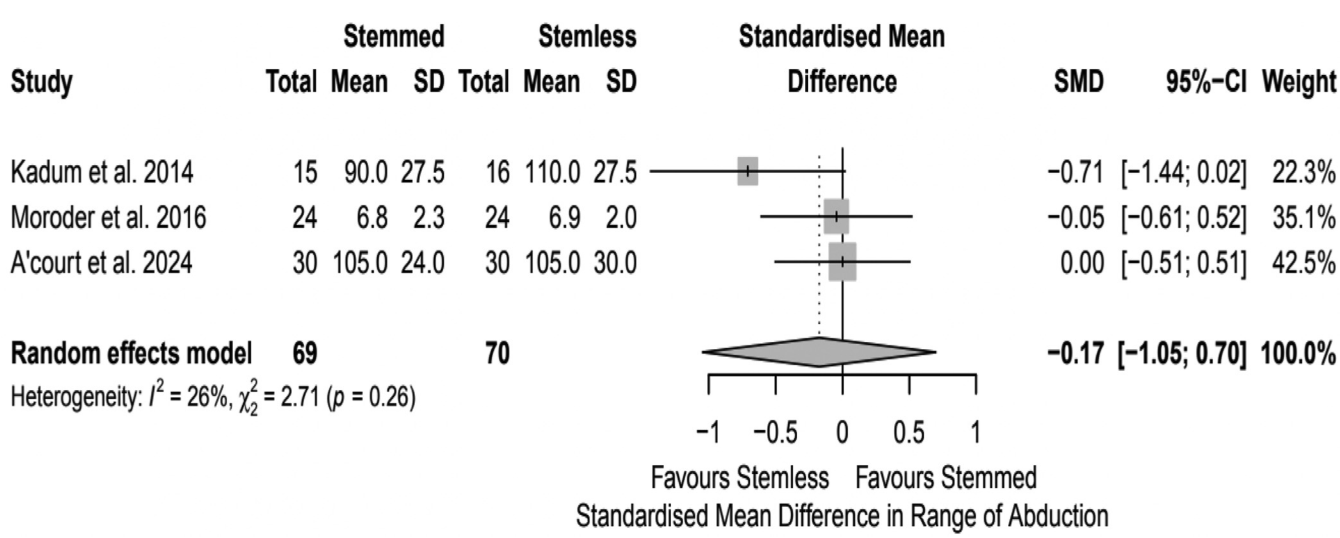

Figure 3 Abduction (AB) meta-analysis of stemless vs. stemmed rTSA. *SD*, standard deviation; *CI*, confidence interval; *SMD*, standardized mean difference; *rTSA*, reverse total shoulder arthroplasty.

0.50). There was a statistically significant difference for IR (SMD -0.79, 95% CI: −1.56, −0.03) in favor of stemless over stemmed designs, suggesting a mechanical advantage of the former over the latter. IR scores following conventional stemmed rTSA are known to be inferior when compared to anatomic stemmed TSA as a result of its intrinsically medialized design despite efforts to offset this through lateralization of either glenoid or humeral components or variation of humeral implant NSA placement.[16,21,35] The clinical implication of achieving improved postoperative IR is reflected its importance for performing tasks included in the ADLIER (Activities of Daily Living which require active External Rotation [ER]) scoring system (activities of daily living which require active IR), such as dressing and toileting.[21] Restoration of basic functionality and independence is paramount, particularly when considering a treatment that is offered primarily to an elderly patient demographic. The mean age of patients across studies included in this systematic

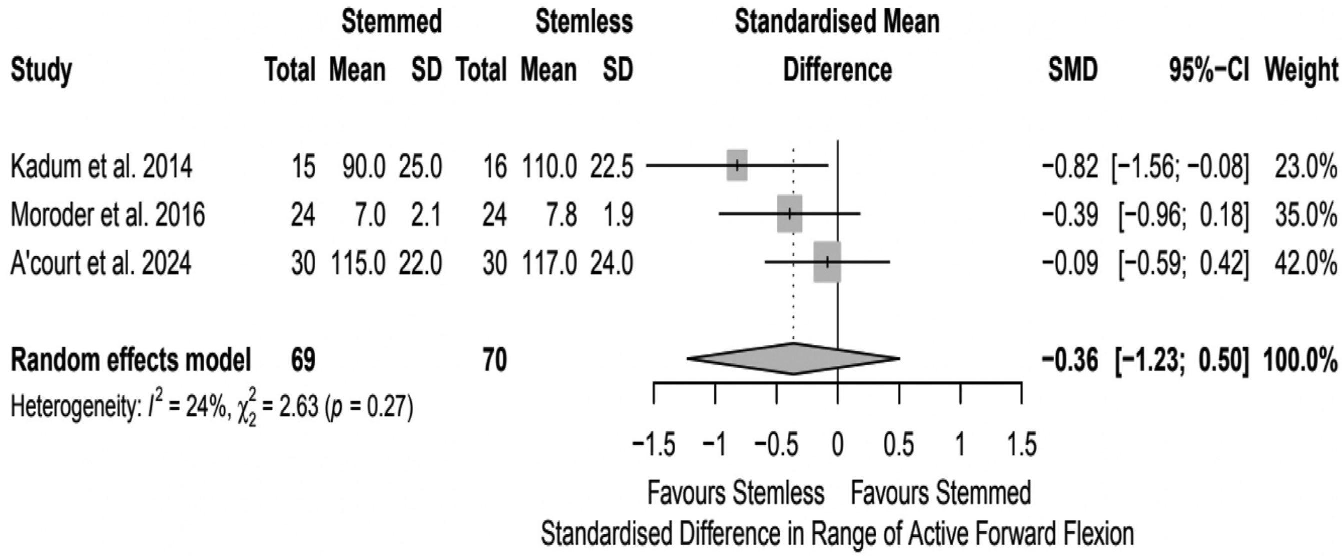

Figure 4 Active forward flexion (FF) meta-analysis of stemless vs. stemmed rTSA. *SD*, standard deviation; *CI*, confidence interval; *SMD*, standardized mean difference; *rTSA*, reverse total shoulder arthroplasty.

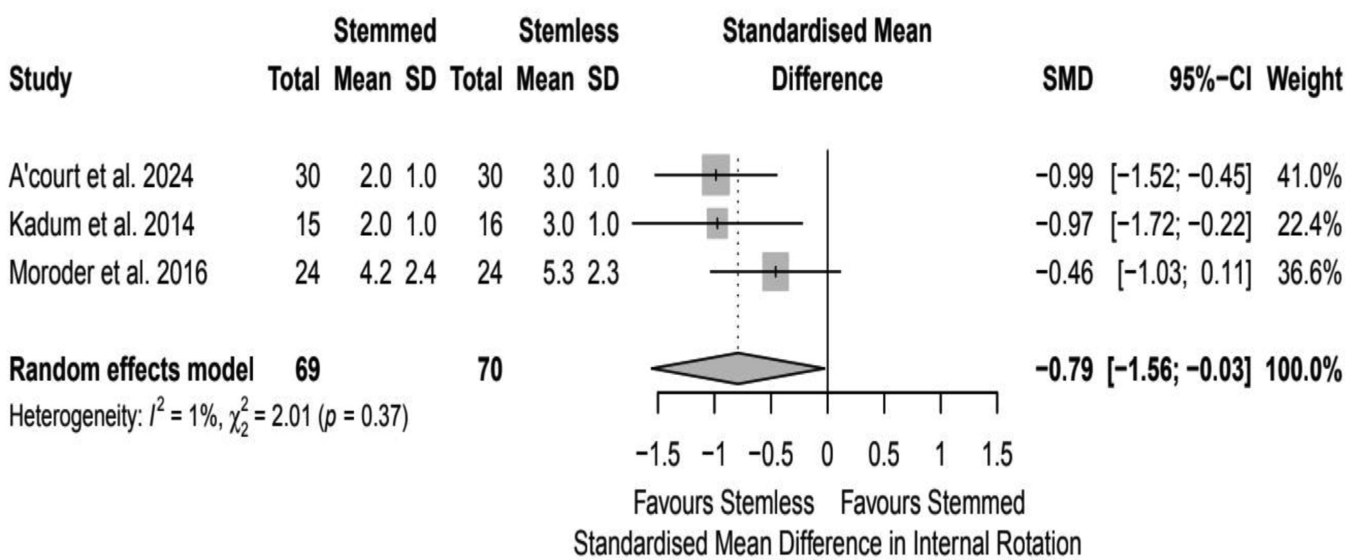

Figure 5 Internal rotation (IR) meta-analysis of stemless vs. stemmed rTSA. *SD*, standard deviation; *CI*, confidence interval; *SMD*, standardized mean difference; *rTSA*, reverse total shoulder arthroplasty.

review was 70. Of the three comparative studies, Moroder et al were the only group to measure postoperative radiographic humeral NSAs. They found the stemless group had an average NSA of 135 degrees compared to 155 degrees in the stemmed group, subsequently linking the superior IR measurements to the steeper inclination angle. Existing literature on the subject matter is somewhat conflicting with much of the information coming from simulation studies. Despite this, there still appears to be a trend toward steeper inclination angles offering advantages in IR.[16,19,21,24,35,41]

With regard to functional outcomes in our meta-analysis, there was no statistically significant difference in VAS (SMD −0.31, 95% CI: −2.32, 1.69) between stemmed and stemless rTSA groups. Similarly for overall complications (OR: 0.82, 95% CI: 0.2, 3.42) and revision rates (OR: 1.02, 95% CI: 0.92, 1.14), there were no significant differences.

Suggested advantages, in existing literature, of stemless rTSA include shorter operative times, reduced blood loss, avoidance of proximal humeral stress shielding, preservation of humeral bone stock, and ease of revision if required.[12,27,28] Despite there being many theoretical advantages of stemless rTSA, evidence of such advantages through robust clinical trials is lacking. Only one of the fifteen studies in this review commented on surgical time or intraoperative blood loss. Moroder et al found operative times to be significantly less in the stemless cohort vs. stemmed (80.5 vs. 109.5 minutes $P < .001$), albeit in a relatively small matched group of 24 patients (48 total). Meta-analysis on a larger scale by Liu et al including 224 patients across 3 studies who received stemless *anatomic* TSA found operative times to be significantly shorter than stemmed groups ($P = .0008$)[26]; technically separate from rTSA but lending credence to the idea that stemless designs reduce operative times. Furthermore, Moroder et al is the only group in this

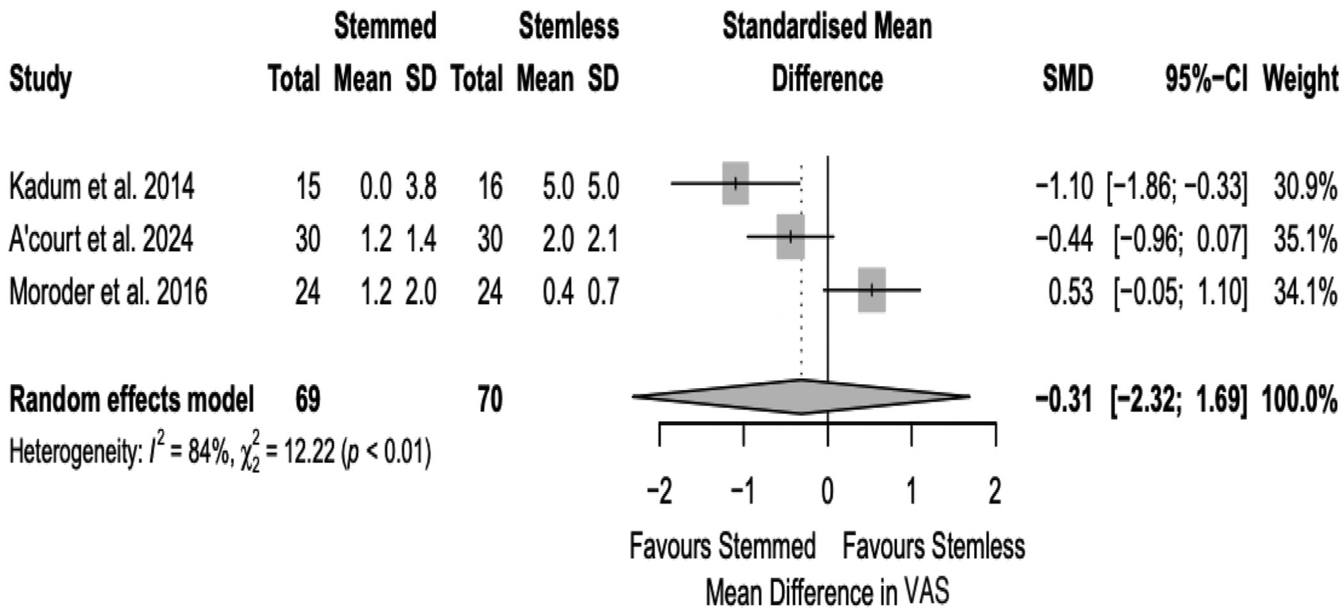

Figure 6 Visual analog scale (VAS) meta-analysis of stemmed vs. stemless rTSA. *SD*, standard deviation; *CI*, confidence interval; *SMD*, standardized mean difference; *rTSA*, reverse total shoulder arthroplasty.

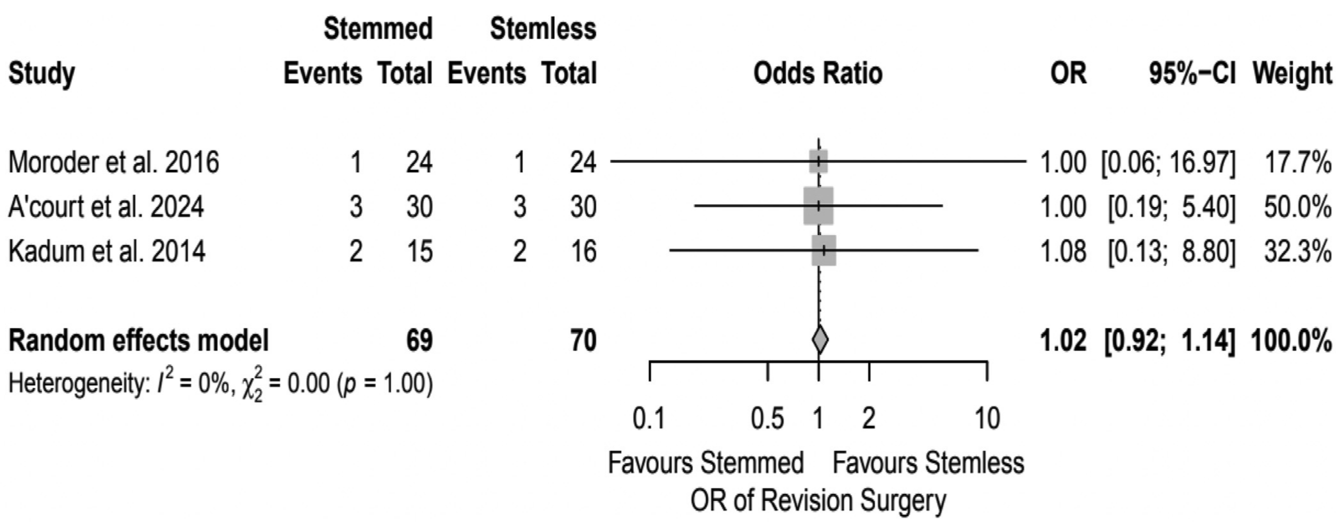

Figure 7 Revision surgery meta-analysis of stemmed vs. stemless rTSA. *CI*, confidence interval; *OR*, odds ratio; *rTSA*, reverse total shoulder arthroplasty.

systematic review that investigates surgical blood loss whereby two patients in the stemmed group required postoperative blood transfusions compared to zero in the stemless group—a finding that was not of statistical significance ($P = .180$). Interestingly, in the same study, the stemless rTSA group had a significantly longer hospital stay (11.8 vs. 7.9 days, $P = .006$), with no clear explanation from the authors as to why. The length of stay quoted in this study seems to be well in excess of the authors' experience with rTSA patients. Length of hospital stay was not commented on elsewhere in the literature in relation to stemless rTSA. The implication of this lack of data in key areas where stemless rTSA designs are often quoted in the literature as having an intrinsic advantage over their stemmed counterparts,[1,22,27-29] raises questions about the credibility of some of the sources of information surrounding stemless rTSA. In any case, due to the paucity of information, the authors of this study did not include such theoretical advantages as reduced blood loss, shorter surgical times, and reduced hospital stay in our quantitative analysis.

Overall complication rates of stemless rTSA studies, in this review, were 13.4%. This figure is in line with other pooled analyses of rTSA, not limited to stemless designs, ranging between 6.5% and 13.7%.[14,24,28,34,45] This finding echoes some of the points raised above, which expose gaps in existing research for conclusive data favoring stemless rTSA over other more established design types that are supported by robust trials with sufficient follow-up periods. Across all studies, implant loosening occurred in 3.1% and dislocation in 1.2%. A 2022 systematic review by Galvin et al[14] of all primary reverse rTSA reported slightly lower loosening rates (0.7%) and dislocation rates (0.7%). A longer stem length that extends distal to the metaphysis has the mechanical advantage of an increased anchor support for the prosthesis. In one of the included comparison studies (stemmed vs. stemless), A'Court et al reported

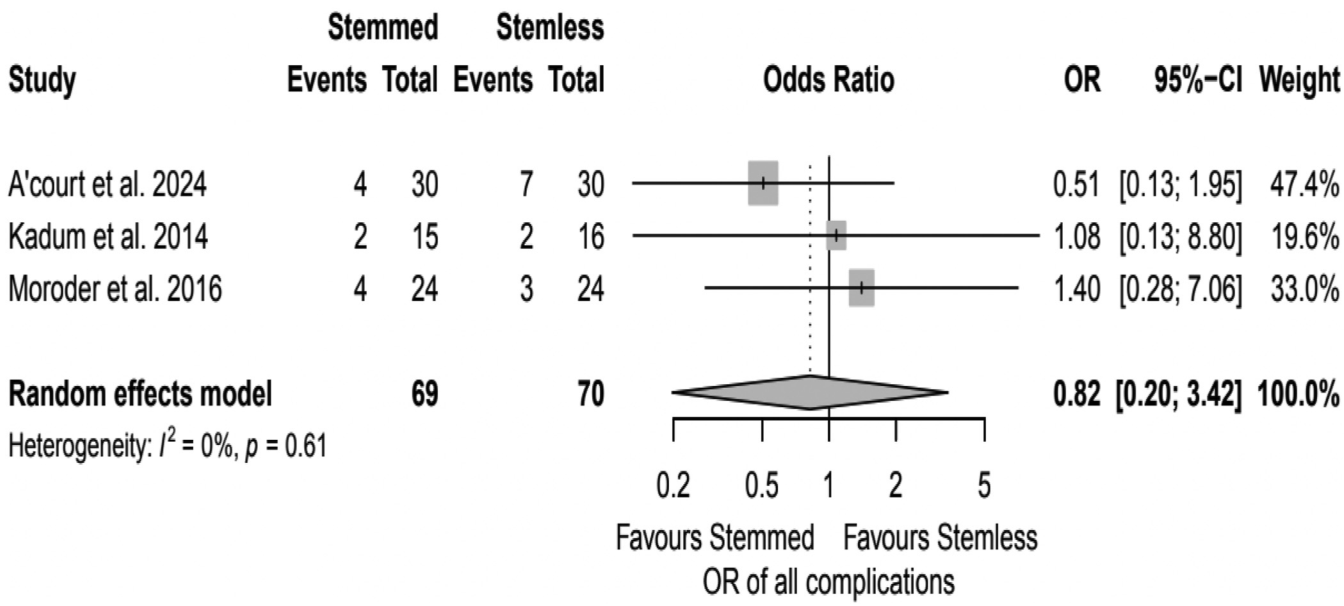

Figure 8 Overall complications meta-analysis of stemmed vs. stemless rTSA. *CI*, confidence interval; *OR*, odds ratio; *rTSA*, reverse total shoulder arthroplasty.

Table IV
Complication rates in stemless rTSA by implant type.

Authors	Year	Implant type	pts, n	Complication rate	Weighted mean complication rate by implant
Virani et al[42]	2021	Verso	21	0.14	**0.18**
Leonidou et al[25]	2020	Verso	37	0.19	
Consigliere et al[8]	2021	Verso	36	0.19	
Moroder et al[29]	2020	TESS	36	0.13	**0.10**
Kadum et al[20]	2014	TESS	16	0.13	
Beck et al[6]	2019	TESS	27	0.15	
Ballas et al[4]	2013	TESS	56	0.16	
Teissier et al[39]	2015	TESS	91	0.03	
A'Court et al[1]	2024	SMR	30	0.23	**0.19**
Willems et al[44]	2024	SMR	12	0.17	
Schoch et al[33]	2021	SMR	52	0.10	
Rosso et al[31]	2023	SMR	26	0.35	
Galhoum et al[13]	2022	Nano	15	0.20	**0.20**
Antoni et al[3]	2024	Easytech	90	0.06	**0.12**
Nabergoj et al[30]	2023	Easytech	115	0.16	

rTSA, reverse total shoulder arthroplasty.

two cases of implant loosening (13% incidence) in the stemless group and found no similar cases in the stemmed group. They suggest that a possible reason for these differences relate to a lack of clarity around the optimum neck shaft resection angle that should be used for stemless rTSA. Much of the biomechanical design considerations and suggested surgical approaches for stemless rTSA have been extrapolated from research on stemless *anatomic* rTSA implants, despite the differences in loads experienced by the humerus in each model. Such differences can result in increased shear forces and less compression at the implant articulation which may predispose to implant instability in stemless rTSA designs.[15,28]

A stemless design system has the advantage of allowing the surgeon to freely choose their humeral NSA. The corollary of this being that there is a greater margin for error in the hands of less experienced surgeons. Average NSA in the stemless group in the study by Moroder et al was 135 degrees (range, 116-152 degrees), significantly steeper than the stemmed group at 155 degrees ($P <$ .001). Interestingly too, the stemless group was fitted with *TESS* implants intended for 155 degree placement, not 135. Despite this, their reported instability rates are in keeping with meta-analysis by Erickson et al including 2222 rTSAs showing no statistically significant difference in dislocation rates between 155 (2.83%) and 135 (1.74%) degree placement groups ($P = .443$).[11] We found the overall incidence of early humeral or glenoid loosening events to be 3.1% in the stemless groups compared to 2.9% in the stemmed groups across the included comparative studies ($P = .436$).

To date, there are no widely accepted criteria for deciding when to use stemless rTSA designs. Teissier et al suggest a selection criteria to assess metaphyseal bone quality intraoperatively before proceeding with reverse implants with clarification of an intact cortical ring post humeral head osteotomy, sufficient bone stock ("thumb test"), and an absence of cysts at the osteotomy site. Development of a common assessment guideline might help mitigate risk and improve selection for stemless rTSA cases.

Scapular notching rates were difficult to accurately ascertain and compare due to variable reference to the grading systems used. For the sake of comparison across all studies, the individual grades were disregarded and we instead focused on the incidence of overall cases of scapular notching. The overall incidence of scapular notching in the included stemless rTSA studies was 19.1%. However, the reported incidence ranges across individual studies is highly variable. Beck et al reported a 0% incidence, whereas Kadum et al reported a 72.3% incidence. These disparities are possibly due to a tendency toward subjective radiological reporting techniques without clear referencing to a scapular notching grading system such as the Nerot-Sirveaux classification. Scapular notching rates in primary rTSA regardless of implant type have been reported in the range of 14.4-18.4% in previous systematic reviews.[2,14,27,45]

Strengths and limitations

Strengths of this study relate to its stringent methodology in the screening, collection, and data analysis phases in accordance with PRISMA guidelines. To our knowledge, this is the first meta-analysis of direct comparison studies between stemmed and stemless rTSA clinical outcomes. The recent comparison study by A'Court in 2024 brought the aggregate to three comparative studies, meeting the minimum threshold for meta-analysis. Hatta et al performed a meta-analysis of the individual complications in the stemless rTSA studies but not a meta-analysis directly comparing stemless and stemmed functional outcomes or ROM parameters.

There are a number of limitations to our study. There is a paucity of high-quality studies with not one included randomized study. A number of studies had conflicts of interest with surgeons either being sponsored by implant companies or the trial being funded directly by these companies. There was often a lack of data stratification and differences in surgical techniques. Many of the studies did not offer preoperative and postoperative clinical scores or ROM and thus a relative improvement could not be measured or compared between all studies. The follow-up times of studies included were relatively short (mean follow-up time was 45 months). The lack of studies with long-term follow-up can be explained by the fact that stemless rTSA has only become popular in Europe in the last decade. The lack of long-term follow-up data has significant implications for assessing the safety profile of these designs, raising questions about the long term durability and stability of the models. The absence of studies included with long-term follow-up periods dilutes the strength of conclusions drawn in this review. Given stemless rTSA implants have yet to be available in US markets, there is a geographical bias with most studies (13/15) occurring in Europe. Based on our ROB analysis, 14 out of 15 studies included serious ROB with one showing moderate ROB. In particular, the disparities around scapular notching reporting suggested serious risks of bias in the measurement of outcomes. The age profile of the patients in each study was predominantly advanced. Little can be concluded from our study about the implications of stemmed vs. stemless implant decisions in the younger population. There were only three comparative studies included in our meta-analysis, which is the minimum threshold for meta-analysis but further studies would strengthen the significance of the results.

Conclusion

Stemless rTSA is emerging as a viable option in the treatment of a range of shoulder injuries. This review shows there to be an advantage of improved postoperative IR in favor of stemless rTSA over its stemmed counterpart. Given that IR is critical for performing the most basic of activities of daily living (ADLs), such as personal hygiene upkeep, and that deficits in IR following rTSA are not uncommon,[16,21,35] a design type that improves this outcome is both beneficial for patients and progressive for orthopedic surgery. No significant differences can be seen in revision rates or overall complication rates when comparing stemmed and stemless rTSA. The proposed advantages of stemless rTSA such as reduced intraoperative times, reduced blood loss, and preserved bone stock are poorly explored in the existing literature. Stemless rTSA trials in Europe have shown promising early and midterm results, comparable with stemmed rTSA. Long-term outcome studies are still required to see how they perform over time. It can be expected that surgeons will await the arrival of robust long-term outcomes before routinely offering stemless rTSA to patients given the lack of convincing evidence favoring their usage over more established design types.

Disclaimers:

Funding: All authors declare that no outside funding or grants were received in support of this work.
Conflicts of interest: The authors, their immediate families, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

References

1. A'Court JJ, Chatindiara I, Fisher R, Poon PC. Does the stemless reverse arthroplasty compare to a conventional stemmed implant? Clinical and radiographic evaluation at 2 years' minimum follow-up. J Shoulder Elbow Surg 2024;33: 1938-45. https://doi.org/10.1016/j.jse.2024.01.030.
2. Ajibade DA, Yin CX, Hamid HS, Wiater BP, Martusiewicz A, Wiater JM. Stemless reverse total shoulder arthroplasty: a systematic review. J Shoulder Elbow Surg 2022;31:1083-95. https://doi.org/10.1016/j.jse.2021.12.017.
3. Antoni M, Bouche PA, Obert L, Quemener A, Nourissat G. Stemless RSA shows good short-term radiological stability and clinical outcomes in elderly patients. Seminars Arthroplasty JSES 2024;24:S1045452724000671. https://doi.org/10.1053/j.sart.2024.04.010.
4. Ballas R, Béguin L. Results of a stemless reverse shoulder prosthesis at more than 58 months mean without loosening. J Shoulder Elbow Surg 2013;22:e1-6. https://doi.org/10.1016/j.jse.2012.12.005.
5. Baulot E, Garron E, Grammont PM. [Grammont prosthesis in humeral head osteonecrosis. Indications–results]. Acta Orthop Belg 1999;65:109-15.
6. Beck S, Patsalis T, Busch A, Dittrich F, Dudda M, Jäger M, et al. Long-term results of the reverse Total Evolutive Shoulder System (TESS). Arch Orthop Trauma Surg 2019;139:1039-44. https://doi.org/10.1007/s00402-019-03135-5.
7. Buch B, Vall M, Consigliere P, Guillén JA, Cruz E, Natera L. Short stems and stemless shoulder arthroplasty: current concepts review. Arch Bone Jt Surg 2022;10:633-47. https://doi.org/10.22038/ABJS.2021.53555.2664.
8. Consigliere P, Witney-Lagen C, Natera L, Sforza G, Bruguera J, Abraham R, et al. Outcome of a metaphyseal reverse total shoulder replacement in rheumatoid arthritis. Musculoskelet Surg 2022;106:257-68. https://doi.org/10.1007/s12306-021-00706-x.
9. DerSimonian R, Kacker R. Random-effects model for meta-analysis of clinical trials: an update. Contemp Clin Trials 2007;28:105-14. https://doi.org/10.1016/j.cct.2006.04.004.
10. Dieckmann R, Liem D, Gosheger G, Henrichs MP, Höll S, Hardes J, et al. Evaluation of a reconstruction reverse shoulder for tumour surgery and tribological comparision with an anatomical shoulder arthroplasty. Int Orthop 2013;37: 451-6. https://doi.org/10.1007/s00264-012-1771-7.
11. Erickson BJ, Frank RM, Harris JD, Mall N, Romeo AA. The influence of humeral head inclination in reverse total shoulder arthroplasty: a systematic review. J Shoulder Elbow Surg 2015;24:988-93. https://doi.org/10.1016/j.jse.2015.01.001.
12. Frank JK, Siegert P, Plachel F, Heuberer PR, Huber S, Schanda JE. The evolution of reverse total shoulder arthroplasty—from the first steps to novel implant designs and surgical techniques. J Clin Med 2022;11:1512. https://doi.org/10.3390/jcm11061512.
13. Galhoum MS, Elsheikh AA, Wood A, Yin Q, Frostick SP. Anatomic and reverse stemless shoulder arthroplasty: functional and radiological evaluation. J Shoulder Elb Arthroplast 2022;6: 247154922211187. https://doi.org/10.1177/24715492221118765.
14. Galvin JW, Kim R, Ment A, Durso J, Joslin PMN, Lemos JL, et al. Outcomes and complications of primary reverse shoulder arthroplasty with minimum of 2 years' follow-up: a systematic review and meta-analysis. J Shoulder Elbow Surg 2022;31:e534-44. https://doi.org/10.1016/j.jse.2022.06.005.
15. Goetti P, Denard PJ, Collin P, Ibrahim M, Mazzolari A, Lädermann A. Biomechanics of anatomic and reverse shoulder arthroplasty. EFORT Open Rev 2021;6:918-31. https://doi.org/10.1302/2058-5241.6.210014.

16. Gruber MD, Kirloskar KM, Werner BC, Lädermann A, Denard PJ. Factors associated with internal rotation after reverse shoulder arthroplasty: a narrative review. JSES Rev Rep Tech 2022;2:117-24. https://doi.org/10.1016/j.xrrt.2021.12.007.
17. Hartung J, Knapp G. On tests of the overall treatment effect in meta-analysis with normally distributed responses. Stat Med 2001;20:1771-82.
18. Hatta T, Mashiko R, Kawakami J, Matsuzawa G, Ogata Y, Hatta W. Evolution of stemless reverse shoulder arthroplasty: current indications, outcomes, and future prospects. J Clin Med 2024;13:3813. https://doi.org/10.3390/jcm13133813.
19. Jeon BK, Panchal KA, Ji JH, Xin YZ, Park SR, Kim JH, et al. Combined effect of change in humeral neck-shaft angle and retroversion on shoulder range of motion in reverse total shoulder arthroplasty — a simulation study. Clin Biomech 2016;31:12-9. https://doi.org/10.1016/j.clinbiomech.2015.06.022.
20. Kadum B, Mukka S, Englund E, Sayed-Noor A, Sjödén G. Clinical and radiological outcome of the Total Evolutive Shoulder System (TESS®) reverse shoulder arthroplasty: a prospective comparative non-randomised study. Int Orthop 2014;38:1001-6. https://doi.org/10.1007/s00264-013-2277-7.
21. Kim MS, Jeong HY, Kim JD, Ro KH, Rhee SM, Rhee YG. Difficulty in performing activities of daily living associated with internal rotation after reverse total shoulder arthroplasty. J Shoulder Elbow Surg 2020;29:86-94. https://doi.org/10.1016/j.jse.2019.05.031.
22. Kostretzis L, Konstantinou P, Pinto I, Shahin M, Ditsios K, Papadopoulos P. Stemless reverse total shoulder arthroplasty: a systematic review of contemporary literature. Musculoskelet Surg 2021;105:209-24. https://doi.org/10.1007/s12306-021-00710-1.
23. Kozak T, Bauer S, Walch G, Al-karawi S, Blakeney W. An update on reverse total shoulder arthroplasty: current indications, new designs, same old problems. EFORT Open Rev 2021;6:189-201. https://doi.org/10.1302/2058-5241.6.200085.
24. Lädermann A, Denard PJ, Boileau P, Farron A, Deransart P, Terrier A, et al. Effect of humeral stem design on humeral position and range of motion in reverse shoulder arthroplasty. Int Orthop 2015;39:2205-13. https://doi.org/10.1007/s00264-015-2984-3.
25. Leonidou A, Virani S, Buckle C, Yeoh C, Relwani J. Reverse shoulder arthroplasty with a cementless short metaphyseal humeral prosthesis without a stem: survivorship, early to mid-term clinical and radiological outcomes in a prospective study from an independent centre. Eur J Orthop Surg Traumatol 2020;30:89-96. https://doi.org/10.1007/s00590-019-02531-2.
26. Liu EY, Kord D, Horner NS, Leroux T, Alolabi B, Khan M. Stemless anatomic total shoulder arthroplasty: a systematic review and meta-analysis. J Shoulder Elbow Surg 2020;29:1928-37. https://doi.org/10.1016/j.jse.2019.12.022.
27. Liu EY, Kord D, Yee NJ, Horner NS, Al Mana L, Leroux T, et al. Stemless reverse total shoulder arthroplasty: a systematic review of short- and mid-term results. Shoulder Elbow 2021;13:482-91. https://doi.org/10.1177/17585732211013356.
28. Luthringer TA, Horneff JG, Abboud JA. Stemless reverse shoulder arthroplasty. J Am Acad Orthop Surg 2024;32:e63-72. https://doi.org/10.5435/JAAOS-D-23-00075.
29. Moroder P, Ernstbrunner L, Zweiger C, Schatz M, Seitlinger G, Skursky R, et al. Short to mid-term results of stemless reverse shoulder arthroplasty in a selected patient population compared to a matched control group with stem. Int Orthop 2016;40:2115-20. https://doi.org/10.1007/s00264-016-3249-5.
30. Nabergoj M, Lädermann A, Authom T, Beaudouin E, Azar M, Wahab H, et al. Stemless reverse shoulder arthroplasty: clinical and radiologic outcomes with minimum 2 years' follow-up. J Shoulder Elbow Surg 2023;32:e464-74. https://doi.org/10.1016/j.jse.2023.01.042.
31. Rosso C, Kränzle J, Delaney R, Grezda K. Radiologic, clinical, and patient-reported outcomes in stemless reverse shoulder arthroplasty at a mean of 46 months. J Shoulder Elbow Surg 2024;33:1324-30. https://doi.org/10.1016/j.jse.2023.10.003.
32. Scarlat MM. Complications with reverse total shoulder arthroplasty and recent evolutions. Int Orthop 2013;37:843-51. https://doi.org/10.1007/s00264-013-1832-6.
33. Schoch C, Plath JE, Ambros L, Geyer M, Dittrich M. Clinical and radiological outcomes of a stemless reverse shoulder implant: a two-year follow-up in 56 patients. JSES Int 2021;5:1042-8. https://doi.org/10.1016/j.jseint.2021.07.007.
34. Shah SS, Roche AM, Sullivan SW, Gaal BT, Dalton S, Sharma A, et al. The modern reverse shoulder arthroplasty and an updated systematic review for each complication: part II. JSES Int 2021;5:121-37. https://doi.org/10.1016/j.jseint.2020.07.018.
35. Sheth M, Kitziger R, Shah AA. Understanding loss of internal rotation after reverse shoulder arthroplasty: a narrative review of current literature. JSES Rev Rep Tech 2024;4:647-53. https://doi.org/10.1016/j.xrrt.2024.03.001.
36. Somes GW. The generalized mantel−haenszel statistic. Am Stat 1986;40:106-8.
37. Sterne JA, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ 2016;12: i4919. https://doi.org/10.1136/bmj.i4919.
38. Teissier J, Teissier P. Stemless shoulder arthroplasty. Orthop Traumatol Surg Res 2023;109: 103460. https://doi.org/10.1016/j.otsr.2022.103460.
39. Teissier P, Teissier J, Kouyoumdjian P, Asencio G. The TESS reverse shoulder arthroplasty without a stem in the treatment of cuff-deficient shoulder conditions: clinical and radiographic results. J Shoulder Elbow Surg 2015;24:45-51. https://doi.org/10.1016/j.jse.2014.04.005.
40. Upfill-Brown A, Satariano N, Feeley B. Stemless shoulder arthroplasty: review of short and medium-term results. JSES Open Access 2019;3:154-61. https://doi.org/10.1016/j.jses.2019.07.008.
41. Virani NA, Cabezas A, Gutiérrez S, Santoni BG, Otto R, Frankle M. Reverse shoulder arthroplasty components and surgical techniques that restore glenohumeral motion. J Shoulder Elbow Surg 2013;22:179-87. https://doi.org/10.1016/j.jse.2012.02.004.
42. Virani S, Holmes N, Al-Janabi M, Watts C, Brooks C, Relwani J. Intermediate to long term results of stemless metaphyseal reverse shoulder arthroplasty: A five to nine year follow-up. J Clin Orthop Trauma 2021;23: 101611. https://doi.org/10.1016/j.jcot.2021.101611.
43. Wasserman S, Hedges LV, Olkin I. Statistical methods for meta-analysis. J Educ Stat 1988;13:75.
44. Willems JIP, Achten G, Crowther MAA, Heikenfeld R, Karelse A, Van Noort A. Two-year follow-up of the SMR stemless platform shoulder system: a multicenter, prospective clinical study. JSES Int 2024;8:888-94. https://doi.org/10.1016/j.jseint.2024.04.005.
45. Willems JIP, Hoffmann J, Sierevelt IN, van den Bekerom MPJ, Alta TDW, van Noort A. Results of stemless shoulder arthroplasty: a systematic review and meta-analysis. EFORT Open Rev 2021;6:35-49. https://doi.org/10.1302/2058-5241.6.200067.
46. Zhou Y, Frampton C, Hirner M. Medium-term results of stemless, short, and conventional stem humeral components in anatomic total shoulder arthroplasty: a New Zealand Joint Registry study. J Shoulder Elbow Surg 2023;32:1001-8. https://doi.org/10.1016/j.jse.2022.10.029.