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

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Background: Stemless anatomic total shoulder arthroplasty (TSA) is used in the treatment of osteoarthritis of the shoulder joint and other degenerative shoulder diseases. It has several proposed advantages over stemmed TSA including increased bone preservation, decreased operative time, and easier removal at revision.

Methods: A systematic search was conducted using MEDLINE, Embase, PubMed, and CENTRAL (Cochrane Central Register of Controlled Trials) to retrieve all relevant studies.

Results: The literature search yielded 1417 studies, of which 22 were included in this review, with 962 patients undergoing stemless TSA. Stemless TSA led to significant improvements in range of motion and functional scores in all included studies. Meta-analysis of comparative studies between stemless and stemmed TSA identified no significant differences in postoperative Constant scores (mean difference [MD], 1.26; 95% confidence interval [CI], –3.29 to 5.81 points; $P = .59$) or complication rates (odds ratio, 1.79; 95% CI, 0.71-4.54; $P = .22$). Stemless TSA resulted in a significantly shorter operative time compared with stemmed TSA (MD, –15.03 minutes; 95% CI, –23.79 to –6.26 minutes; $P = .0008$). Stemless TSA also resulted in significantly decreased intraoperative blood loss compared with stemmed TSA (MD, –96.95 mL; 95% CI, –148.53 to –45.36 mL; $P = .0002$).

Conclusion: Stemless anatomic TSA resulted in similar functional outcomes and complication rates to stemmed TSA with decreased operative time and lower blood loss. Further research is required to investigate the long-term durability of the stemless implant.

Level of evidence: Level IV; Systematic Review

Keywords: Total shoulder arthroplasty; complication; shoulder; stemless arthroplasty; systematic review; meta-analysis

Since the introduction of total shoulder arthroplasty (TSA) in 1974, prosthesis design has evolved to better approximate the natural anatomy of the glenohumeral joint.[5,13,29] Multiple iterations of the implant have been introduced to improve the design and better accommodate anatomic variability in the proximal humerus.[13,31]

Institutional review board approval was not required for this systematic review.

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Current-generation implants have transitioned to shorter humeral stem lengths or even stemless components. Stemless shoulder arthroplasty, also termed ''canal-sparing shoulder arthroplasty,'' was first introduced by Biomet (Warsaw, IN, USA) in 2004.[6] Since then, various other manufacturers have introduced stemless prosthesis designs to the market. The stemless prosthesis has been suggested to yield several advantages including improved bone preservation, decreased stress shielding, shorter operative time, and easier removal at revision.[13] These advantages have contributed to the current popularity of stemless TSA.

The use of stemless shoulder implants is expected to surpass that of stemmed implants by 2025 in European markets.[18] Given this increasing popularity of the stemless implant, it is important to evaluate the currently available evidence on the advantages and disadvantages of stemless implants. Our objective was, therefore, to systematically review the available literature to assess and report clinical and radiologic outcomes after stemless anatomic TSA.

Methods

Search strategy and eligibility

A search was conducted in Ovid Medline (1946 to week 3 of October 2018), Embase (1974 to week 3 of October 2018), CENTRAL (Cochrane Central Register of Controlled Trials) (up to October 31, 2018), and PubMed (up to October 20, 2018) by 1 reviewer (E.Y.L.) using the keyword ''shoulder'' combined with ''arthroplasty'' combined with ''stem*'' limited to humans and English (Supplementary Table S1). The inclusion criteria were (1) studies reporting clinical and/or radiologic outcomes after stemless anatomic TSA, (2) studies published in English, and (3) studies on humans. Studies were excluded if they were (1) nonsurgical studies (eg, review articles, technique articles, and cadaveric studies), (2) surgical studies that did not separate outcomes between stemless TSA and other surgical procedures, or (3) radiologic studies that did not report any clinical outcomes.

Study selection

We followed the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines to systematically screen studies.[28] Two reviewers (D.K. and E.Y.L.) independently screened the titles and abstracts of the studies identified through the literature search. Relevant articles were retrieved and rescreened for eligibility based on the full-text articles. Any disagreements at the title and abstract stage or the full-text review stage were resolved either by consensus or through discussion with a third reviewer (N.S.H.). The references of the included articles were also hand searched to identify additional articles that met the eligibility criteria.

Data collection

Data were collected independently by 2 reviewers (D.K. and E.Y.L.). Disagreements were resolved either by consensus or through discussion with a third reviewer (N.S.H.). The collected data include study characteristics (eg, author, article title, year of publication, study design, and sample size), patient information (eg, age, sex, and diagnosis), surgery information (eg, surgical technique and implant), major clinical outcomes after surgery (eg, range of motion [ROM] and functional scores), major radiologic outcomes after surgery (eg, radiolucency and loosening), and complications (eg, type of complication, management of complications, and revision surgery). We also recorded whether the authors had conflicts of interest or commercial sources of funding.

Quality assessment of included studies

The quality of the studies was assessed independently by 2 reviewers (D.K. and E.Y.L.) using the Methodological Index for Non-randomized Studies (MINORS) appraisal tool for observational studies and the Cochrane risk-of-bias tool for randomized controlled trials.[16,35] Disagreements were resolved through consensus or discussion with a third reviewer (N.S.H.).

The MINORS appraisal tool was used to evaluate the quality of observational studies.[35] A score of 0, 1, or 2 was assigned to each of the 12 criteria on the MINORS checklist, resulting in a maximum score of 16 for noncomparative studies and 24 for comparative studies.[35] The MINORS scores for comparative studies were categorized as follows: 0-6 indicated very low quality of evidence; 7-10, low quality of evidence; 10-16, fair quality of evidence; and greater than 16, good quality of evidence.

The internal validity of randomized controlled trials was assessed using the Cochrane risk-of-bias tool.[16] A rating of low, high, or unclear risk was given for selection bias, performance bias, detection bias, attrition bias, reporting bias, and other bias based on in-text evidence.[16]

Statistical analysis

Descriptive statistics

Means, standard deviations (SDs), and ranges were calculated and presented when applicable. Weighted means and weighted SDs, which take into consideration the different sample sizes of studies, were also presented when possible. Confidence intervals (CIs) were calculated using mean, SD, and sample size when applicable. Follow-up time was categorized as follows: short term (0-2 years), midterm (2-10 years), or long term (>10 years).

Inter-rater agreement

The κ statistic indicating inter-reviewer agreement was calculated for all screening stages and categorized as follows: 0.81-0.99, excellent agreement; 0.61-0.80, substantial agreement; 0.41-0.60, moderate agreement; 0.21-0.40, fair agreement; and 0.20 or less, slight agreement.[24]

Meta-analysis

Review Manager (version 5.3 [2014]; The Cochrane Collaboration, London, UK) was used to perform the meta-analysis. Continuous data such as the Constant score and operative time were presented as mean differences (MDs) with 95% CIs. Dichotomous data such as complication rate were presented as odds ratios (ORs) with 95% CIs. The heterogeneity of results within the included studies was measured with χ^2 and I^2 statistics. $P < .05$ was considered significant for the χ^2 test. The I^2 test was categorized as follows: 0.0%-24.9%, no heterogeneity; 25.0%-49.9%, low heterogeneity; 50.0%-74.9%, moderate heterogeneity;

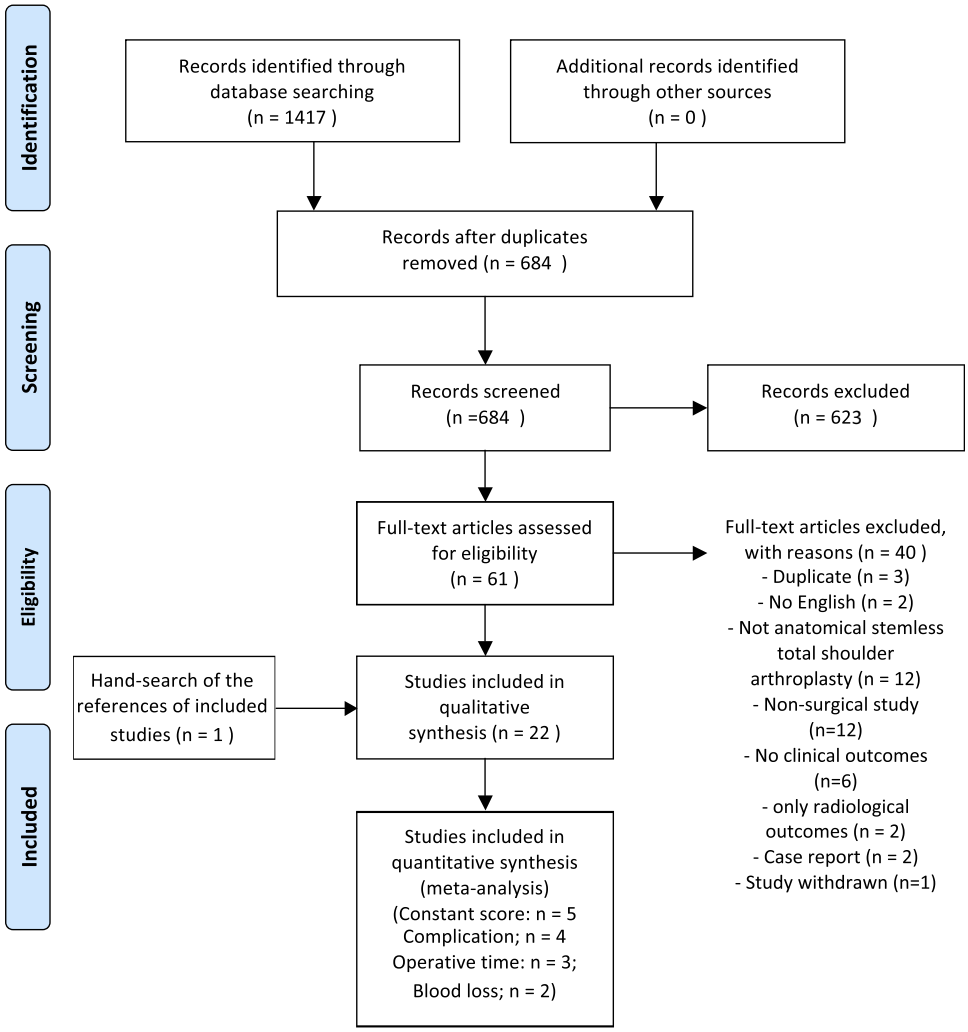

Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-analyses (*PRISMA*) flow diagram.

and 75.0%-100.0%, high heterogeneity.[17] In addition, a random-effects model was used in all meta-analyses because of expected clinical heterogeneity. We also intended to perform assessment of publication bias through an Egger regression and symmetry of funnel plots if appropriate.[9]

Complications

Complication and revision data were extracted from included studies whenever possible. Events were recorded as complications if either the authors reported them as complications or the patient underwent revision. We did not count radiolucency, osteolysis, and other radiologic changes as complications and reported them separately under radiologic outcomes.

Results

Included studies

The literature search identified a total of 1417 studies, of which 22 were included in this systematic review following full-text review (Fig. 1). Two of the included studies were conducted on the same patient cohort and reported non–completely overlapping outcomes.[20,33] Both studies were included, but the patient cohort was included only once in outcome calculation. There was good agreement between reviewers at the title and abstract (κ, 0.702; 95% CI, 0.603-0.800) and full-text (κ, 0.728; 95% CI, 0.556-0.900) review stage.

Demographic characteristics

A total of 962 patients underwent stemless anatomic TSA in the included studies. The mean sample size per study was 45.8 patients with stemless TSA (SD, 37.5 patients; range, 9-149 patients). The weighted mean age of patients was 67.6 years, and 47.5% of the included patients were female patients. The included studies were conducted in the following countries: Australia (1)[4] (number of stemless patients [$n_{stemless}$] = 50); Austria (2)[15,30] ($n_{stemless}$ = 59); Canada (1)[32] ($n_{stemless}$ = 17); France, Japan, and Germany (1)[8] ($n_{stemless}$ = 47); Germany (8)[3,5,12,14,25,26,36,38] ($n_{stemless}$ = 162); Germany, Austria, Switzerland, France, the United

Kingdom, and Italy (1)[23] ($n_{stemless}$ = 73); Italy (2)[27,37] ($n_{stemless}$ = 103); Sweden (4)[19-21,37] ($n_{stemless}$ = 199); the United Kingdom (1)[10] ($n_{stemless}$ = 103); and the United States (1)[7] ($n_{stemless}$ = 149).

Follow-up

Regarding follow-up, 10 studies (48%) had short-term follow-up (0-2 years)[4,19-21,23,25,27,30,32,33] ($n_{stemless}$ = 386), 11 studies (52%) had mid-term follow-up (2-10 years)[3,5,7,8,10,12,14,15,36-38] ($n_{stemless}$ = 564), and no studies had long-term follow-up (>10 years). In addition, 1 study (5%) did not report the length of follow-up ($n_{stemless}$ = 12).[26]

Competing interests

A total of 8 studies (36%) reported that the authors had competing interests or commercial sources of funding, 12 studies (55%) reported no competing interests, and 2 studies (9%) did not report on competing interests.

Quality assessment and risk of bias

Of the 22 included studies, 18 (81%) were nonrandomized in design and their quality was assessed using the MINORS score (Supplementary Table S2). Of the nonrandomized studies, 3 were Level II, 1 was Level III, and 14 were Level IV. The remaining 4 included studies (18%) were randomized controlled trials, which were evaluated using the Cochrane risk-of-bias tool (Supplementary Table S3). The nonrandomized studies can be further divided into noncomparative and comparative studies. The mean MINORS score for noncomparative studies (14 studies) was 11.3 ± 2.6 of 16, indicating that the noncomparative studies were fair in quality. The mean MINORS score for comparative studies (4 studies) was 15.8 ± 1.9 of 24, indicating that the comparative studies were fair in quality (Supplementary Table S2).

Most of the included studies reported a clearly stated aim, prospective collection of data, endpoints appropriate to the aim of the study, and follow-up period appropriate to the aim of the study. However, many studies failed to report or perform unbiased assessment of endpoints and prospective calculations of sample size. There was also substantial loss to follow-up in many of the included studies. The comparative studies had appropriate and contemporary control groups but could improve on equivalence at baseline and adequate statistical analysis such as reporting CIs and risk ratios (Supplementary Table S2). An assessment for publication bias using Egger regression or symmetry of funnel plots was not performed because of the low number of studies included in the meta-analysis.[9]

Surgical information

Prosthesis

The stemless prosthesis type was reported in 950 patients (21 studies). The Eclipse prosthesis (Arthrex, Munich, Germany) was used in 316 patients (33%). The TESS prosthesis (Biomet) was used in 219 patients (23%). The Simpliciti (Tornier SAS, Montbonnot, France) was used in 196 patients (21%), and other prostheses were used in 229 patients (23%) (Table I).

Table I Stemless anatomic TSA prosthesis type summary

Prosthesis	Patients, n (%)
TESS (Zimmer Biomet, Warsaw, USA)	219 (23.1)
Simpliciti (Tornier SAS, Montbonnot, France)	196 (20.6)
Eclipse (Arthrex, Munich, Germany)	316 (33.3)
Comprehensive Total Shoulder system (Zimmer Biomet)	87 (9.2)
Sidus Stem-Free Shoulder System (Zimmer Biomet)	73 (7.7)
Mathys (Mathys, Bettlach, Switzerland)	50 (5.3)
Aequalis shoulder prosthesis system (Tornier SAS)	9 (0.9)
Total	950

TSA, total shoulder arthroplasty.

Table II Stemless TSA indication summary

Indication	Patients, n (%)
Primary OA	749 (93.6)
Post-traumatic OA	28 (3.5)
Degenerative shoulder pathology not otherwise specified	12 (1.5)
Aseptic osteonecrosis	6 (0.7)
Post-instability arthritis	4 (0.5)
Humeral head necrosis	1 (0.1)
RA	1 (0.1)
Total	801

TSA, total shoulder arthroplasty; *OA*, osteoarthritis; *RA*, rheumatoid arthritis

Indications

The indication for surgery was reported in 801 patients (18 studies). Most patients (93.6%) underwent stemless anatomic TSA because of primary osteoarthritis. Other indications included post-traumatic osteoarthritis (3.5%), degenerative shoulder disease not otherwise specified (1.5%), aseptic osteonecrosis (0.7%), post-instability arthritis (0.5%), humeral head necrosis (0.1%), and rheumatoid arthritis (0.1%) (Table II).

Surgical approach

The surgical approach was reported in 868 patients (21 studies). Only 2 surgical approaches were used: the deltopectoral approach in 761 patients (88%) and the anterosuperior approach in 107 patients (12%) (Table III).

Clinical outcomes

Range of motion

Flexion was reported for 425 stemless anatomic TSA patients (12 studies). Weighted mean flexion increased from 90° ± 16° preoperatively to 142° ± 17° postoperatively. Abduction was reported for 368 patients (11 studies). Weighted mean abduction increased from 70° ± 16° preoperatively to 130° ± 21° postoperatively. The change in flexion and abduction was significant in all included studies that reported these outcomes (Table IV).

Internal rotation was only reported for 193 stemless anatomic TSA patients (2 studies). Weighted mean internal rotation increased from 52° ± 30° preoperatively to 67° ± 21° postoperatively. External rotation was reported for 712 stemless anatomic TSA patients (13 studies). In total, weighted mean external rotation increased from 23° ± 10° preoperatively to 47° ± 11° postoperatively (Table IV). Weighted mean ROM was also analyzed by prosthesis manufacturer (Table V).

Functional scores

Significant variability in the functional outcome scores used to assess shoulder function was reported in the included studies. Some studies also reported multiple functional scores. The functional scores used included the Constant score; Simple Shoulder Test (SST) score; American Shoulder and Elbow Surgeons shoulder score; Disabilities of the Arm, Shoulder and Hand (DASH) score; short version of the DASH questionnaire (QuickDASH) score; Oxford Shoulder Score; and Shoulder Pain and Disability Index.

Thirteen studies ($n_{stemless}$ = 596) reported Constant scores. The weighted mean Constant score increased from 35.2 ± 9.1 to 74.6 ± 9.0 points. Four studies ($n_{stemless}$ = 150) reported QuickDASH scores. The weighted average QuickDASH score decreased from 59.3 ± 20.4 to 17.6 ± 5.9 points. Two studies ($n_{stemless}$ = 158) reported SST scores. The weighted mean SST score increased from 4.2 ± 0.6 to 10.5 ± 0.2 points (Table VI).

Five studies reported Constant scores for comparative studies evaluating stemless and stemmed TSA patients, which were included in a meta-analysis. The results demonstrated no difference in postoperative Constant scores between stemless and stemmed TSA (MD, 1.26; 95% CI, –3.29 to 5.81 points, I^2 = 48%; P = .59) (Fig. 2). Limited available data precluded meta-analysis of other functional outcome scores.

Radiologic outcomes

Nine studies ($n_{stemless}$ = 563) reported the number of patients with radiolucency or osteolysis. In total, 10 patients (1.8%) had humeral displacement, 44 (7.8%) had glenoid radiolucent lines (RLLs), 104 (18.4%) had humeral RLLs, and 47 (8.3%) had periprosthetic RLLs not further specified. Furthermore, 3 patients (0.5%) had mild glenohumeral subluxation, and 12 (2.1%) had humeral osteolysis.

Table III Stemless TSA surgical approach summary

Surgical approach	Patients, n (%)
Deltopectoral	761 (88)
Anterosuperior	107 (12)
Total	868

TSA, total shoulder arthroplasty.

Table IV Weighted average range of motion for stemless TSA

Range of motion	No. of reported patients	Preoperative	Postoperative
Flexion, °	425	90 ± 16	142 ± 17
Abduction, °	368	70 ± 16	130 ± 21
Internal rotation, °	193	52 ± 30	67 ± 21
External rotation, °	712	23 ± 10	47 ± 11

TSA, total shoulder arthroplasty.

Complications

Complications were reported for 719 stemless anatomic TSA patients (14 studies). A total of 60 complications occurred, and the overall complication rate was 8.3%. The most common complication was rotator cuff failure (2.2%), followed by infection (1.0%) and glenoid perforation (0.8%). Glenoid loosening occurred in 0.6% of cases, and no postoperative humeral loosening was reported in any of the included studies. A meta-analysis of 4 comparative studies identified no significant difference (P = .22) in complication rates between the 2 groups (OR, 1.79; 95% CI, 0.71-4.54; I^2 = 15%) (Fig. 3).

Revision was reported for 627 stemless anatomic TSA patients (12 studies). A total of 35 revisions were performed, which translates to an overall revision rate of 5.6%. The most common indications for revision included rotator cuff failure (1.8%), glenoid loosening (0.8%), and glenoid failure (0.8%). Complication and revision rates were also analyzed by prosthesis manufacturer (Table VII).

Revision to stemmed and reverse TSA

Eleven studies ($n_{stemless}$ = 500) reported revision to either stemmed or reverse TSA, with revisions to stemmed TSA in 6 cases (1.2%) and revisions to reverse TSA in 8 (1.6%). Most of the stemmed revisions (83%) happened intraoperatively because of insufficient fixation as determined

Table V Weighted mean range of motion of different stemless prostheses

	TESS	Sidus	Eclipse	Simpliciti	Aequalis	Comprehensive
Flexion						
Patients, n	190	73	62	47	9	
Preoperative, °	87	85	121	84	73	
Postoperative, °	140	150	144	131	151	
Abduction						
Patients, n	190		62		9	63
Preoperative, °	74		85		64	51
Postoperative, °	134		133		138	112
External rotation						
Patients, n	152	73	165	196	9	63
Preoperative, °	22.1	12	29.2	28.3	10	17
Postoperative, °	48.8	45	45.3	47.7	45	50

Table VI Weighted average functional scores for stemless TSA

Functional score	No. of reported patients	Preoperative	Postoperative
Constant score	606	35.2 ± 9.2	74.6 ± 8.9
QuickDASH score	150	59.3 ± 20.4	17.6 ± 5.9
Simple Shoulder Test score	168	4.2 ± 0.6	10.5 ± 0.2

TSA, total shoulder arthroplasty; *QuickDASH*, short version of Disabilities of the Arm, Shoulder and Hand questionnaire.

by the operating surgeon. All reverse revisions happened postoperatively because of rotator cuff failure (Table VIII).

Rates of infection

One of the included studies raised the concern that stemless TSA may lead to higher rates of infection: Johansson et al[19] reported that stemless prostheses had higher rates of infection than stemmed TSAs. Specifically, postoperative infections developed in 6 of 92 stemless TSA patients (6.5%) and 1 of 115 stemmed TSA patients (0.9%). However, we were unable to confirm this finding in other included studies. In fact, only a total of 8 infections (0.8%) were reported in the 962 patients included in this review, and 6 of those infections occurred in the study conducted by Johansson et al.

Other outcomes

Operative time

Berth and Pap,[5] Heuberer et al,[15] and Malcherczyk et al[26] compared operative time between stemless anatomic TSA and stemmed TSA patients. Berth and Pap found the operative time to be significantly shorter ($P = .002$) in the stemless group (91.5 ± 14.5 minutes) than the stemmed group (106.2 ± 23.3 minutes). Heuberer et al also found that the operative time was significantly shorter ($P < .001$) in the stemless group (95.7 ± 20.3 minutes) than the stemmed group (120.7 ± 36.4 minutes). Moreover, Malcherczyk et al found the operative time to be shorter in the stemless group (96.6 ± 14.4 minutes) than the stemmed group (104 ± 27.8 minutes), although this difference was not able to reach significance given the lower number of stemless patients in the study ($P = .3748$).

Pooling of the results showed that stemless TSA had significantly shorter operative times than stemmed TSA (MD, –15.03 minutes; 95% CI, –23.79 to –6.26 minutes; $P = .0008$). No heterogeneity was found in the included study results ($I^2 = 0\%$) (Fig. 4).

Blood loss

Berth and Pap[5] and Malcherczyk et al[26] compared total blood loss between stemless anatomic TSA and stemmed TSA. Berth and Pap found blood loss to be significantly lower ($P = .026$) in the stemless group (496.3 ± 116.3 mL) than the stemmed TSA group (593.4 ± 147.0 mL), although no patients in either arm required blood transfusions. Malcherczyk et al also found blood loss to be lower in the stemless group (298.3 ± 189.9 mL) than the stemmed TSA group (394.6 ± 186.3 mL), although their findings did not reach statistical significance ($P = .262$). The reported blood transfusion rate for stemmed TSA was 14.4%, whereas none of the stemless TSA patients required blood transfusions.

Pooled results identified stemless TSA to result in significantly lower intraoperative blood loss compared with stemmed TSA (MD, –96.95 mL; 95% CI, –148.53 to –45.36 mL; $P = .0002$). No heterogeneity was found in the included study results ($I^2 = 0\%$) (Fig. 5).

Discussion

Stemless TSA is one of the latest innovations in shoulder replacement surgery. The proposed benefits of stemless TSA include decreased operative time, decreased blood

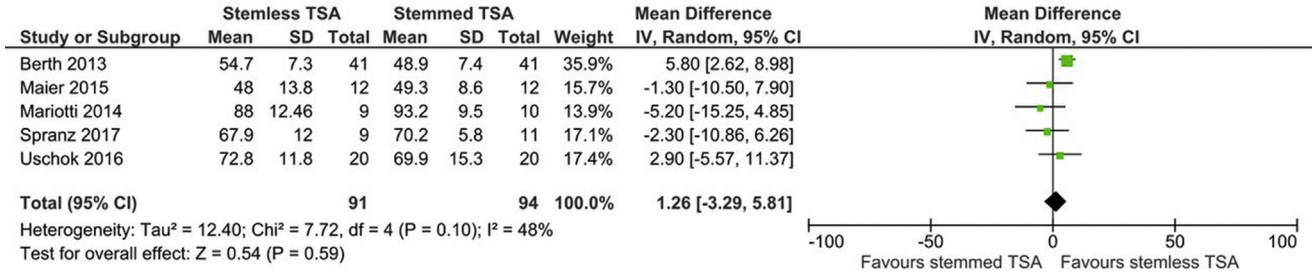

Figure 2 Constant score meta-analysis of stemless vs. stemmed total shoulder arthroplasty (*TSA*). *SD*, standard deviation; *CI*, confidence interval; *IV*, inverse variance.

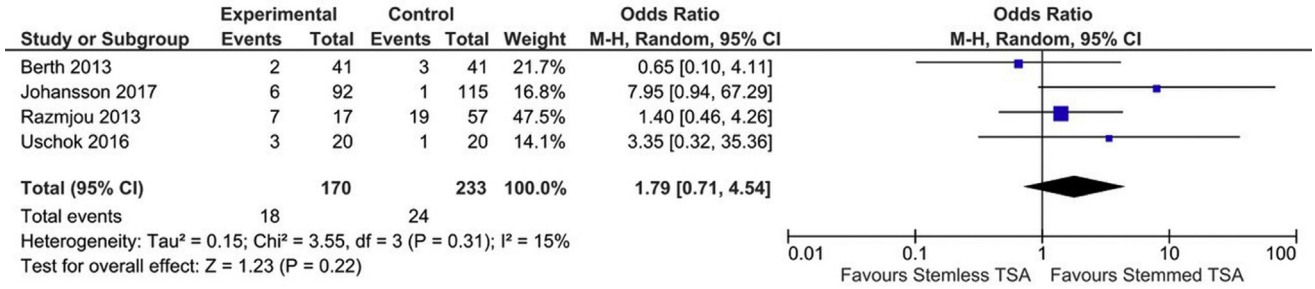

Figure 3 Complication rate meta-analysis of stemless vs. stemmed total shoulder arthroplasty (*TSA*). *M-H*, Mantel-Haenszel; *CI*, confidence interval.

loss, increased bone preservation, and potentially easier revision.[2] For 10 of the 16 rotator cuff failures in the stemless TSA group, the timing of the complication was reported. Of the 10 rotator cuff failures reported, 2 (20%) occurred before 2 years. No rotator cuff failures were reported in the stemmed TSA group. Such outcomes were of particular interest when evaluating the overall effectiveness of the procedure as this is of critical importance in the comparison between stemless and stemmed TSA.

Pooled analysis across studies indicated that stemless TSA had shorter operative times than stemmed TSA (MD, –15.03 minutes; 95% CI, –23.79 to –6.26 minutes; $P = .0008$). Stemless TSA also resulted in decreased intraoperative blood loss compared with stemmed TSA (MD, –96.95 mL; 95% CI, –148.53 to –45.36 mL; $P = .0002$). However, further research is required to determine whether this decreased blood loss reaches a clinically significant threshold for blood transfusion. Nevertheless, these results provide support for the hypothesized benefits of stemless TSA, which may direct surgeons to favor stemless TSA over stemmed TSA in the future.

Stemless TSA led to significant improvements in ROM and shoulder function. The global improvements in ROM were comparable to those of stemmed TSA and exceeded the minimal clinically important difference for TSA as determined by Simovitch et al.[22,34] Stemless TSA also led to significant increases in functional scores. The meta-analysis in this review found no difference in Constant scores between stemless and stemmed TSA. Although the number of studies included in the meta-analysis is limited, both the meta-analysis and comparison to previous literature seem to suggest that stemless TSA and stemmed TSA result in similar clinical outcomes.

Stemless TSA had an overall reported complication rate of 8.3% and an overall revision rate of 5.6%. The complication rates reported in this review are comparable to those reported for stemmed TSA, and pooled analysis found no significance in complication rates between the 2 groups.[1] No cases of postoperative humeral loosening were reported in any of the included studies. The ease of revision was difficult to evaluate in the included studies as authors rarely reported outcomes following revision. On the basis of the available evidence reported by the study authors, it appears that revision surgery was easier in the stemless group because of better bone preservation and easier removal of a stemless humeral component.[4,8,10,15,36,38] The most common reasons for revision were rotator cuff failure (1.8%), glenoid failure (0.8%), and glenoid loosening (0.8%).

The decision to perform intraoperative revision to a stemmed component is determined by the subjective assessment of the surgeon. Two studies reported 5 cases of intraoperative revision to stemmed TSA because the surgeon believed that the stemless implant had insufficient fixation.[7,8] It was difficult to determine whether the intraoperative revisions were warranted as no cases of postoperative humeral loosening were reported in any of the included studies. In addition, there is currently no objective way to assess bone quality at the time of the operation. It would be interesting to compare patient outcomes with or without intraoperative stemmed revision to establish which

Table VII Complication and revision rate of different stemless prostheses

Implant	Patients, n	Complication, %	Revision, %
Eclipse	274	9.5	8.2
Simpliciti	196	5.6	5.6
TESS	190	6.8	4.2
Mathys	50	20	2
Aequalis shoulder prosthesis system	9	0	0

Table VIII Revision to stemmed and reverse TSA

	Intraoperative, n (%)	Postoperative, n (%)
Revised to stemmed TSA	5 (1.0)	1 (0.2)
Revised to reverse TSA	0 (0.0)	8 (1.6)

TSA, total shoulder arthroplasty.

patient groups are truly at risk of humeral loosening and whether revision to a stemmed implant is effective at preventing the onset of humeral loosening. Although no cases of postoperative humeral loosening were reported in this review, this could be because of insufficient follow-up as humeral loosening is mostly a long-term complication and long-term results of stemless TSA are not yet available. Data from long-term studies may be needed to further establish the long-term durability and stability of the stemless implant.[11]

Overall, stemless TSA had high survivorship and low incidences of radiologic changes based on mostly short- and mid-term results. Of the patients, 7.8% had glenoid RLLs, 18.4% had humeral RLLs, and 8.3% had periprosthetic RLLs not further specified. Furthermore, 1.8% had humeral head displacement and/or migration, and 2.1% had humeral osteolysis. However, it is unclear whether this had clinical significance as no cases of postoperative humeral loosening were reported in any of the included studies.

Stemless TSA has been around for almost a decade in Europe but was not available in the United States until recently because of issues with the US Food and Drug Administration. As a result, we believe the use of stemless TSA will continue to grow exponentially within the next few years as the US market grows and adapts to the stemless implant. On the basis of the currently available evidence, stemless TSA results in comparable ROM, functional scores, and complication rates to stemmed TSA. In addition, stemless implants benefit from a shorter operative time and decreased intraoperative blood loss. Stemless TSA also may result in easier revision because of improved bone preservation and easier removal of the stemless implant.[4,8,10,15,36,38] Early results from short- and mid-term studies found no cases of postoperative humeral loosening. These results present stemless TSA as a promising candidate in the treatment of degenerative shoulder disease, although more research may be needed to establish the long-term durability of the implant and outcomes after revision.

Strengths and limitations

The main strength of this review resides in its rigorous methodology. Multiple databases were screened, and the included references were hand searched to identify all relevant studies. In addition, all screening, data extraction, and quality assessment were completed by 2 independent reviewers with good inter-reviewer agreement at all stages. In total, our review included 962 patients. The large sample size allows us to compare clinical outcomes and complications across diverse populations in numerous countries.

However, the strengths of this review were limited by inconsistent outcome reporting in the included studies. Inconsistent reporting existed in the reporting of complications and revision. Although some studies reported even minor complications such as skin irritation due to dressing, others only reported major complications that led to revision. This means that the complication rate reported in this review could be influenced by different definitions of complications and selective reporting by study authors. There were also inconsistencies in terms of which functional scores (eg, Constant, Shoulder Pain and Disability Index, DASH, and QuickDASH scores) were used by the study authors to determine postoperative outcomes, which made it difficult to compare results across studies. Moreover, there were studies that excluded any patients who underwent revision after the procedure in their inclusion and exclusion criteria, which could have caused us to underestimate the number of postoperative revisions. Another area of interest is the ease of revision as this is proposed as a benefit of stemless TSA. However, the included studies rarely reported information about the revision process and outcomes after revision. Future research with improved outcome reporting following revision surgery will lend clarity on the matter.

Finally, there were several studies in which the authors combined results from stemless TSA and stemless shoulder hemiarthroplasty, reporting them together without separating the 2 groups. We excluded these studies if the authors reported no separate outcomes between stemless TSA and stemless shoulder hemiarthroplasty per our exclusion criteria because we were only interested in outcome after stemless TSA; however, we realize this means that some patients who underwent stemless TSA were not included in our review because of reporting issues. We encourage

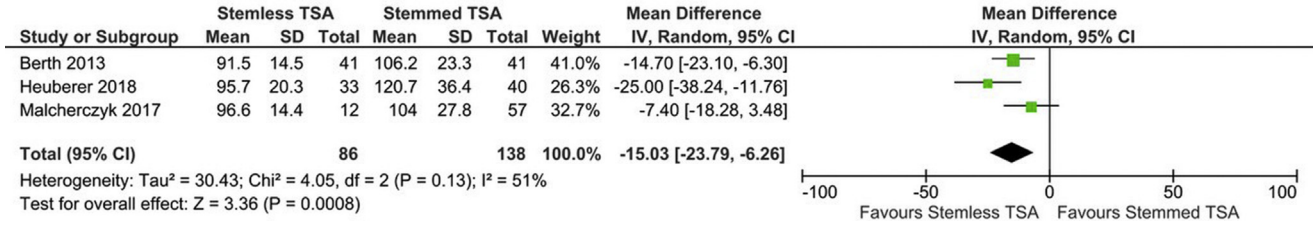

Figure 4 Operative time meta-analysis of stemless vs. stemmed total shoulder arthroplasty (*TSA*). *SD*, standard deviation; *CI*, confidence interval; *IV*, inverse variance.

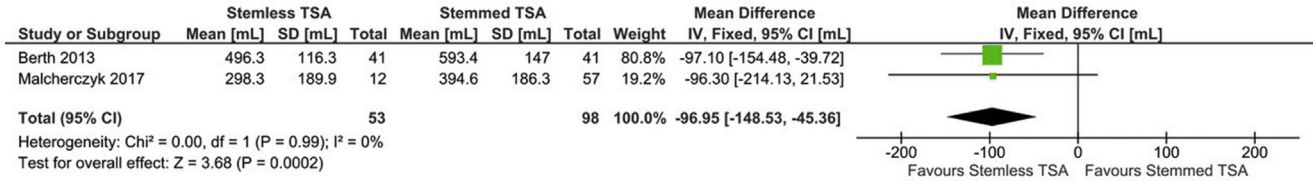

Figure 5 Blood loss meta-analysis of stemless vs. stemmed total shoulder arthroplasty (*TSA*). *SD*, standard deviation; *CI*, confidence interval; *IV*, inverse variance.

authors to report outcomes of stemless TSA and stemless hemiarthroplasty separately in the future to better differentiate outcomes between the procedures.

Conclusion

Preliminary evidence suggests that stemless TSA is able to achieve similar clinical outcomes to stemmed TSA with the added advantage of a shorter operative time and decreased intraoperative blood loss. Further research is required to investigate the long-term durability of the stemless implant.

Disclaimer

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Supplementary Data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jse.2019.12.022.

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