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Stemless reverse total shoulder arthroplasty: a systematic review

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Background: The use of reverse total shoulder arthroplasty and stemless anatomic total shoulder replacement has been increasing in the United States every year. Stemless humeral components in reverse total shoulder arthroplasty are only approved for clinical trials in the United States with an investigational device exception with limited data.

Methods: A systematic review on stemless reverse total shoulder arthroplasty was conducted according to Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines. A search was conducted on November 25, 2020, using the MEDLINE/PubMed, Cochrane, and Embase databases. All articles were reviewed by 2 independent evaluators, with any conflicts or issues resolved by consensus or a final decision by the senior author. The primary outcomes extracted were complications, radiographic results, and outcome scores.

Results: We evaluated 10 studies that used either the Total Evolutive Shoulder System (TESS) or Verso implant. There were 430 total patients and 437 total procedures; 266 patients in the TESS group underwent a total of 272 procedures, and 164 patients in the Verso group underwent a total of 165 procedures. The mean age at the time of surgery was 73.8 years (range, 38-93 years). The mean follow-up period ranged from 6.4 to 101.6 months per study. There was an overall trend of improved clinical outcome scores, a 0.2% humeral component loosening rate, and an 11.2% complication rate.

Conclusions: This review shows that the clinical and functional outcomes following stemless or metaphyseal reverse total shoulder arthroplasty are quite promising, especially with the low rate of humeral-sided complications. There continues to be a need for additional long-term studies and randomized clinical trials.

Level of evidence: Level IV; Systematic Review

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Keywords: Stemless reverse total shoulder; reverse total shoulder; stemless total shoulder; systematic review; humeral loosening; complication; outcomes

Reverse total shoulder arthroplasty (rTSA) was approved for use in the United States >15 years ago for the treatment rotator cuff tear arthropathy (CTA).[62] Numerous articles have been published reporting its efficacy in treating pain and improving function.[48] Positive outcomes have been reported following rTSA for the treatment of glenohumeral arthritis with severe rotator cuff deficiency, fracture sequelae, revision arthroplasty, pseudoparesis due to rotator cuff dysfunction, rheumatoid arthritis, and tumors of the proximal humerus.[10,17,18,21,31,51,61,64]

The understanding of rTSA implant biomechanics, fixation techniques, and associated complications has improved concurrently with the increased incidence and expanding indications of the procedure.[11,30,35,52,56,59] The focus on bone preservation, anticipation of revision

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

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procedures, and limitation of adverse outcomes associated with stemmed humeral components has catalyzed the development of stemless implants in anatomic shoulder arthroplasty. Loss of bone stock, intraoperative and postoperative periprosthetic fractures, malpositioning of components, and more difficult eradication of periprosthetic infections have been associated with humeral stems.[8,9,15,19,28] Stress shielding of the proximal humerus can also occur with diaphyseal fixation of stemmed implants.[46,49] These considerations fostered the development of stemless and metaphyseal humeral components for anatomic total shoulder arthroplasty (aTSA).[26,34] With the increased use of stemless aTSA, stemless rTSA is now being investigated and used for similar considerations.

Stemless implants preserve proximal humeral bone stock, which can simplify revision surgery, avoid metadiaphyseal defects, and reduce intraoperative and postoperative periprosthetic fractures.[5,6,8,16,57] It also obviates the need to prepare the diaphysis, which can decrease blood loss and operative time.[7]

Stemless humeral implants also have several disadvantages that emphasize the importance of careful patient selection. If bone quality, in terms of density and cystic degeneration and/or defects, is in question, a stemmed implant would offer more stability with diaphyseal engagement. Designs that do not require a standard humeral neck cut can also make glenoid exposure more technically challenging with increased importance of precise positioning, soft-tissue release, and retractor placement.[63] Standard stemless implants allow for improved glenoid exposure relative to designs that require more limited head resection.[7,23]

There has been a steady rise of stemless aTSA with promising short- and long-term clinical results.[5,12,16,24,27,40,50,57] However, this trend has not yet occurred with stemless rTSA, with very few published studies on clinical and functional outcomes.[1,3,6,32,33,38,45,55,58] For this reason, we sought to explore and review the current literature to describe, summarize, and evaluate the outcomes and complications following stemless rTSA.

Methods

A systematic review was conducted according to Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines.[42] A search was conducted on November 25, 2020, using the MEDLINE/PubMed, Cochrane, and Embase databases. The electronic search was carried out with the following algorithm: (''reverse total shoulder arthroplasty'' OR ''reverse total shoulder replacement'' OR ''rTSA'' OR ''reverse shoulder arthroplasty'' OR ''reverse shoulder replacement'') AND (''stemless'' OR ''non-stemmed'' OR ''metaphyseal'' OR ''short-stem'' OR ''short-stemmed''). A manual reference check of previous reviews and published studies was conducted to identify any additional relevant studies. Articles were filtered out based on the following exclusion criteria: (1) non–English-language text; (2) availability of only an abstract; (3) treatment using aTSA, stemmed rTSA, or hemiarthroplasty; (4) review article or meta-analysis; and (5) case report. The treatments reviewed included stemless rTSA and metaphyseal rTSA. All articles eligible after the screening phase were reviewed and evaluated for inclusion criteria, relevant clinical outcome score data, and complications. All articles were reviewed and assessed by 2 independent evaluators. Any conflicts or issues were resolved by consensus of the evaluators or, if necessary, a final decision by the senior author. Included articles that met the criteria were analyzed for quality, and data were extracted. Authors, publication year, journal title, level of evidence, study design, surgical procedure, operative technique, indication for surgery, number of patients, average age at the time of surgery, sex, average follow-up period, complications, radiographic results, and outcome scores were extracted from the included articles. In studies that included multiple surgical treatments, relevant data pertaining to this study were stratified and analyzed independently (Fig. 1). Because of the small number of studies available and variations in reporting of data, statistical analysis of results was limited to certain groupings of studies as detailed in the ''Results'' section.

Results

Twelve studies from 2011 to 2019 were included for qualitative analysis, with 2 studies excluded from quantitative analysis. Of the studies, 7 evaluated the Total Evolutive Shoulder System (TESS) prosthesis (Biomet, Warsaw, IN, USA) and 5 evaluated the Verso prosthesis (Innovative Design Orthopaedics, London, UK [formerly Biomet, Swindon, UK]).[1,3,6,32,33,38,45,55,58] The 2014 study by Kadum et al[33] and the 2016 study by Levy et al[38] are updated studies with the same cohorts as the 2011 study by Kadum et al[32] and the 2014 study by Atoun et al,[1] respectively. As such, they were excluded during quantitative analysis. The studies used various outcome measures, with the Constant score (CS) being the most common. Other scores used included the following: American Shoulder and Elbow Surgeons (ASES) score; Quick Disabilities of the Arm, Shoulder and Hand (QuickDASH) score; Oxford Shoulder Score; Subjective Shoulder Score (SSV); Subjective Shoulder Test score; visual analog scale score; pain score; and personal patient satisfaction score. Range of motion (ROM) and radiographic findings were also reported. The grade of scapular notching was reported per the Sirveaux classification.[54]

Description of implants

Verso implant

The humeral component of the Verso implant is a short metaphyseal-only implant with 3 tapered, thin titanium porous and hydroxyapatite-coated fins that provide immediate metaphyseal press-fit fixation (Figs. 2 and 3). The

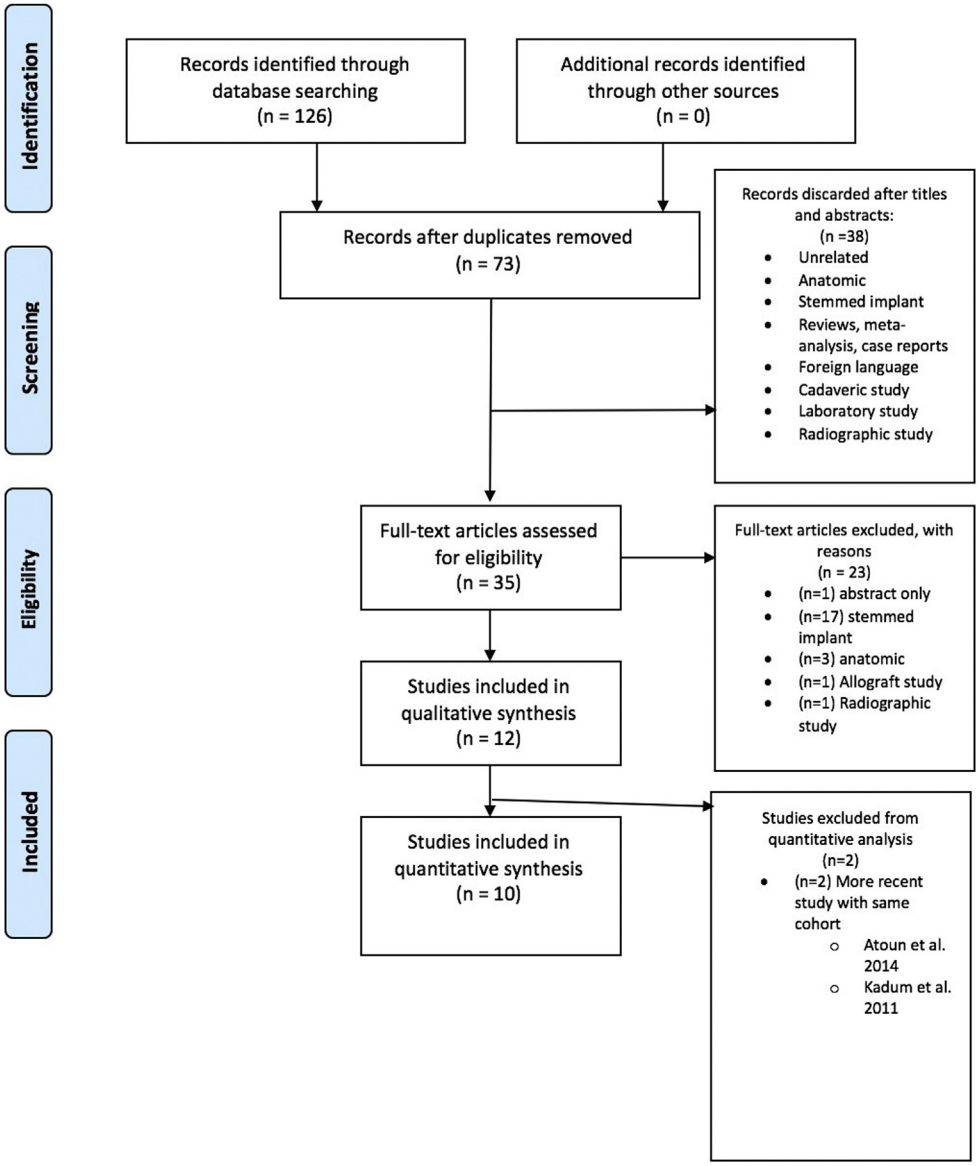

Figure 1 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) flowchart.

glenoid baseplate has a central tapered screw that is hydroxyapatite-coated titanium and 2 additional superior and inferior screws. The glenosphere is fixed with a Morse taper to the baseplate. The polyethylene humeral liners have a 10° inclined shape, achieved by removing the redundant polyethylene inferomedially and on each side on both sides. The humeral cut is performed at a 155° angle, with a final implant angle of 145° using the inclined liner.

TESS implant

The TESS implant allows multiple shoulder arthroplasty variations to be performed using the same humeral component. The humeral cup is made of cobalt-chrome with a titanium plasma spray and hydroxyapatite coating. The polyethylene is clipped inside the cup and held by a metal ring. The surface of the humeral cup is composed of 6 anti-rotational wings and is available in 4 sizes (Figs. 4 and 5). The glenoid baseplate is secured by a full hydroxyapatite central peg with plasma spray with superior and inferior 4.5-mm locked screws. The glenosphere is composed of cobalt-chrome and is available in 2 diameters (36 and 41 mm).

Qualitative summary of studies

TESS implant

Kadum et al[32] (2011) evaluated the short-term results of 49 aTSA and rTSA patients; 17 stemless rTSA patients were included in the study (Table I). Outcome scores were not

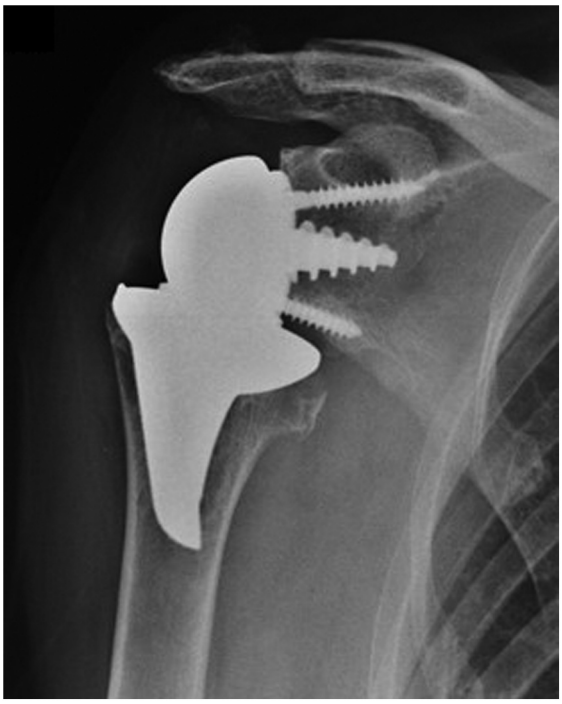

Figure 2 Radiograph of Verso implant. Reprinted with Permission from Springer.

Figure 3 Verso implant.

stratified by implant. Complications included instability due to a malpositioned glenosphere in 1 patient and dislocation due to migration of the humeral cup in 1 patient, which was treated with revision to a stemmed prosthesis.

Ballas and Beguin[3] (2013) evaluated the outcomes of 56 TESS patients at a mean of 58 months (range, 38-95 months). The mean CS improved from 29 ± 8 preoperatively to 62 ± 12 postoperatively. The mean Oxford score improved from 46 ± 5 to 17 ± 4 (range, 12-30) postoperatively. No cases of humeral radiolucency, migration,

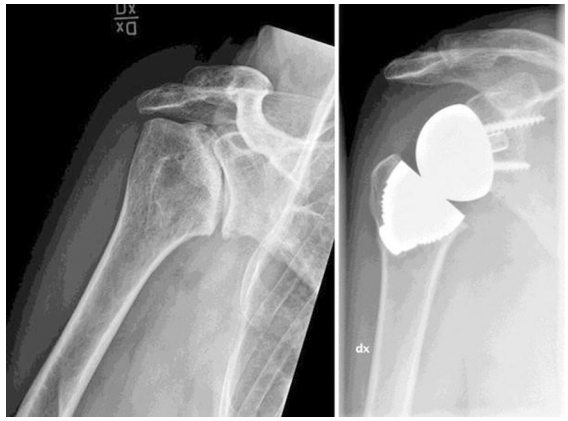

Figure 4 Radiograph of Total Evolutive Shoulder System implant. Reprinted with Permission from Springer.

Figure 5 Total Evolutive Shoulder System implant. Reprinted with Permission from Elsevier.

or loosening were noted at final follow-up; however, there was 1 case of significant greater tuberosity lysis. Sirveaux grade 1 scapular notching was noted in 5 shoulders (9%). One patient experienced an intraoperative partial humeral metaphyseal fracture, but primary stability was maintained with no secondary displacement of the implant. One patient receiving anti–vitamin K medication required surgical evacuation of a hematoma. One patient had a superficial infection that was treated conservatively. One patient had a rupture of the subscapularis diagnosed at the 1-year postoperative visit. One patient had a stress fracture of the acromion that occurred 4 years postoperatively and was treated conservatively. Revision surgery was required in 4 cases (7%) owing to dissociation of glenoid components (3 patients) and instability (1 patient). Of the patients who had dissociation of glenoid components, 2 were treated with reverse prostheses with primary stems; the remaining patient was treated with a simple implant removal. The patient with instability had displacement of the humeral cup

Table I Summary of study characteristics, including study design, LOE, and demographic data

Title	Authors	Journal	Year	Study design	LOE	Implant	Patients, n	Total cases, n	Mean follow-up, mo	Follow-up range, mo	Mean age, yr	Age range, yr	Sex: M:F, n
"Results of the Total Evolutive Shoulder System (TESS): a single-centre study of 56 consecutive patients"	Kadum et al[32,*]	Arch Orthop Trauma Surg	2011	Case series	IV	TESS	17	17	14	9-24	71	59-83	NR
"Results of a stemless reverse shoulder prosthesis at more than 58 mo mean without loosening"	Ballas and Beguin[3]	J Shoulder Elbow Surg	2013	Case series	IV	TESS	56	56	59	38-95	74	55-85	16:40
"Reverse shoulder arthroplasty with a short metaphyseal humeral stem"	Atoun et al[1,†,‡]	Int Orthop	2014	Case series	IV	Verso	31	31	36	24-52	73.5	58-93	10:21
"Clinical and radiological outcome of the Total Evolutive Shoulder System (TESS(R)) reverse shoulder arthroplasty: a prospective comparative non-randomised study"	Kadum et al[33,*]	Int Orthop	2014	Comparative	IV	TESS	16	16	35	15-66	69	62-76	10:6
"The TESS reverse shoulder arthroplasty without a stem in the treatment of cuff-deficient shoulder conditions: clinical and radiographic results"	Teissier et al[55,‡]	J Shoulder Elbow Surg	2015	Case series	IV	TESS	87	91	41	24-69	73	55-89	61:26
"Short-term results of the reverse Total Evolutive Shoulder System (TESS) in cuff tear arthropathy and revision arthroplasty cases"	Von Engelhardt et al[58]	Arch Orthop Trauma Surg	2015	Case series	IV	TESS	56	56	17.5	NR	73.2	NR	NS
"Short to mid-term results of stemless reverse shoulder arthroplasty in a selected patient population compared to a matched control group with stem"	Moroder et al[45]	Int Orthop	2016	Comparative	IV	TESS	24	24	34.2	24-75	75.6	NR	7-17

(*continued on next page*)

Table I Summary of study characteristics, including study design, LOE, and demographic data (*continued*)

Title	Authors	Journal	Year	Study design	LOE	Implant	Patients, n	Total cases, n	Mean follow-up, mo	Follow-up range, mo	Mean age, yr	Age range, yr	Sex: M:F, n
"Reverse shoulder arthroplasty with a cementless short metaphyseal humeral implant without a stem: clinical and radiologic outcomes in prospective 2- to 7-yr follow-up study"	Levy et al[38,†,‡]	J Shoulder Elbow Surg	2016	Case series	IV	Verso	98	98	50	24-82	74.4	38-93	20:78
"Revision shoulder arthroplasty from resurfacing to non-cemented short-stem reverse prosthesis"	Natera et al[†,‡]	Rev Esp Cir Ortop Traumatol	2016	Case series	IV	Verso	23	23	43.4	25-101	70.3	NR	4:19
"Long-term results of the reverse Total Evolutive Shoulder System (TESS)"	Beck et al[6]	Arch Orthop Trauma Surg	2019	Case series	IV	TESS	27	29	101.6	75-142	72.4	53-88	5-22
"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"	Leonidou et al[36]	Eur J Orthop Surg Traumatol	2019	Prospective case series	IV	Verso	36	37	36	12-84	76.9	NR	9-27
"Cementless metaphyseal reverse shoulder arthroplasty: our preliminary experience"	Micheloni et al[41]	Acta Biomed	2019	Comparative	IV	Verso	7	7	6.43	5-9	77.33	65-88	2-5

LOE, level of evidence; *M*, male; *F*, female; *TESS*, Total Evolutive Shoulder System; *NR*, not reported; *NS*, not stratified; *Arch Orthop Trauma Surg*, *Archives of Orthopaedic and Trauma Surgery*; *J Shoulder Elbow Surg*, *Journal of Shoulder and Elbow Surgery*; *Int Orthop*, *International Orthopaedics*; *Rev Esp Cir Ortop Traumatol*, *Revista Española de Cirugía Ortopédica y Traumatología*; *Eur J Orthop Surg Traumatol*, *European Journal of Orthopaedic Surgery and Traumatology*; *Acta Biomed*, *Acta Bio Medica: Atenei Parmensis*.

[*] Authors include Kadum and Sayed-Noor.

[†] Authors include Levy and Atoun.

[‡] Authors include implant designer and/or co-developer.

during passive external rotation and was treated with revision to a stemmed implant.

The study by Kadum et al[33] (2014) was a nonrandomized, prospective, comparative study of the TESS stemless version vs. the TESS stemmed version for rTSA with a modified anterosuperior Mackenzie approach as described by Molé et al.[43] There were 16 patients in the stemless group. The mean QuickDASH score improved from 67 preoperatively to 29 postoperatively. No radiologic signs of humeral implant loosening were noted, but glenoid loosening was seen in 2 shoulders and required revision with baseplate exchange. Scapular notching was seen in 4 patients. There were 2 cases of humeral cup displacement (12.5%) that required revision.

Von Engelhardt et al[58] (2015) evaluated and compared the TESS vs. a stemmed implant for rTSA in patients with CTA (52 cases) and patients in need of revision arthroplasty (4 cases). Of the 67 procedures performed in 65 patients, 56 involved a stemless implant. Outcome scores, radiologic results, and complications were not stratified by the implant received. In the combined group, the mean CS improved from 11.3 to 78.8 and the Disabilities of the Arm, Shoulder and Hand score improved from 73.7 to 31.8. Regarding the reported complications, aseptic loosening of the humeral component was observed in the revision arthroplasty group and was treated with conversion to a stemmed implant. Humeral loosening was not detected in any of the patients who had CTA. Scapular notching was noted in 9 cases; however, it is unclear whether this occurred in the stemless or stemmed cohort.

Teissier et al[55] (2015) analyzed the results of 91 TESS stemless rTSAs in 87 patients. Of the patients, 13% had undergone previous rotator cuff surgical treatment. The mean CS improved from 40 to 68. The mean postoperative ASES score was 24, and the mean postoperative QuickDASH score was 20. No radiographic evidence of glenoid or humeral loosening was observed. Scapular notching was noted in 17 cases (19%), with 16 cases in stage 1 and 1 case in stage 2. One patient presented with postoperative instability and underwent revision with the addition of a 6-mm polyethylene spacer. One patient experienced a stress fracture of the spine of the scapula. One patient had a traumatic clavicle fracture after a fall, without any effect on the ultimate result.

Moroder et al[45] (2016) evaluated the short- to mid-term clinical and radiologic outcomes after TESS stemless rTSA in 24 patients. The mean postoperative CS, ASES score, and SSV were 65.4, 76.2, and 86.6, respectively. The average time for implantation was 80.5 minutes, and the average hospital stay was 11.8 days. Radiolucency or visible bone density loss was detected in 3 patients. No overall radiologic loosening of the humeral component was noted. Grade 1 scapular notching was detected in 2 cases. One patient experienced a traumatic dislocation after a fall on a staircase and was treated with polyethylene exchange and subscapularis tendon repair. One patient experienced an acromial spine fracture that was treated conservatively. There was 1 case of symptomatic mesacromion treated with tension-band osteosynthesis, in addition to 3 cases of slight postoperative stiffness all treated conservatively.

Beck et al[6] (2019) reported the long-term results of the TESS in 29 shoulders in 27 patients. Notably, the short stem was used in 17 shoulders, and the postoperative results were not stratified. Overall, the mean CS improved from 13.0 to 60.5 and the QuickDASH score improved from 70.9 to 28.9. Scapular notching of grade 1 (33.3%), grade 2 (22.2%), or grade 3 (16.7%) was noted in a total of 72.3% of patients at final follow-up. A hematoma and instability developed postoperatively in 1 patient with rheumatoid arthritis and CTA; this patient ultimately underwent revision to a stemmed implant. Another patient with baseplate loosening underwent revision to a hemiarthroplasty. One patient had a low-grade infection and required a revision procedure.

Verso implant

Atoun et al[1] (2014) evaluated 31 patients who underwent rTSA with the Verso implant. The mean CS improved from 12.7 to 56.2. There were 2 cases of grade 1 and 2 glenoid notching. Two dislocations occurred that required reoperation. There were 2 cases of intraoperative cracks of the humeral metaphysis during bone graft impaction and 1 case of a cracked glenoid rim, all of which healed with conservative treatment. One acromial stress fracture developed at 3 months postoperatively and healed with conservative treatment. Five patients sustained late traumatic periprosthetic fractures after falls. One patient sustained a glenoid fracture and refused further surgery. Three patients sustained metaphyseal fractures and were treated successfully with conservative measures. One patient sustained a displaced proximal metaphyseal fracture and required revision to a stemmed reverse prosthesis.

Levy et al[38] (2016) evaluated clinical and radiologic outcomes using the Verso implant in 98 patients. The mean CS improved from 14 to 59, and the SSV improved from 8 to 85. On radiographic analysis, no loosening of humeral or glenoid components was observed. Glenoid notching was observed in 21 patients (21.4%), of whom 18 had grade 1 or 2 notching and 3 had grade 3 notching. Two patients had nondisplaced fractures of the humeral metaphysis due to excessive bone impaction; 1 patient had a glenoid rim fracture during preparation. In all 3 patients, healing occurred with conservative treatment. There were 2 early dislocations, both of which required reoperation. One patient had glenosphere dissociation and required revision surgery. Two patients had acromial stress fractures, with 1 requiring operative treatment. Two patients sustained proximal humeral fractures and were treated conservatively. One patient sustained a periprosthetic fracture that required revision to a stemmed reverse prosthesis.

Table II Summary of postoperative outcomes

Authors	CMS		Active FF, °		Active abduction, °		ER, °		IR		Other reported outcome scores
	Preop	Postop	Preop	Postop	Preop	Postop	Preop	Postop	Preop	Postop	
Ballas and Beguin[3] (2013)	29	62	79	140	—	—	13	45	—	—	Oxford score
Kadum et al[33] (2014)	—	—	50	110	30	110	—	—	Sacrum	L3	QuickDASH score, EQ-5D score
Teissier et al[55] (2015)	40	68	96	143	89	138	47	68	—	—	QuickDASH score, ASES score, pain score (0-15)
Moroder et al[45] (2016)	—	65.4	—	—	—	—	—	—	—	—	ASES score, SSV, VAS score
Levy et al[38] (2016)	14	59	47	129	—	—	10	51	21°	65°	SSV, pain score (0-15), VAS score
Natera et al[47] (2016)	17.32	59.78	60	139.57	53.86	126.74	27.73	41.3	24.55°	62.61°	Satisfaction score (0-10)
Beck et al[6] (2019)	13	60.5	51.9	135.5	38.3	116.1	—	—	—	—	QuickDASH score, VAS score
Leonidou et al[36] (2019)	—	63	—	133	—	110	—	30	—	—	Oxford score, ADLEIR score
Micheloni et al[41] (2019)	21.57	56.86	40.7	154.3	52.9	150	3.6	51.4	17.9°	65.7°	SST score, VAS score

CMS, Constant-Murley score; *FF*, forward flexion; *ER*, external rotation; *IR*, internal rotation; *Preop*, preoperative; *Postop*, postoperative; *QuickDASH*, Quick Disabilities of the Arm, Shoulder and Hand; *ASES*, American Shoulder and Elbow Surgeons; *SSV*, Subjective Shoulder Value; *VAS*, visual analog scale; *SST*, Simple Shoulder Test; *ADLEIR*, activities of daily living requiring external and internal rotation.

Natera et al (2016) evaluated 23 cases of revision of anatomic resurfacing arthroplasty to rTSA using the Verso implant. The mean age was 70.3 ± 11.9 years. The mean CS score increased from 17.32 ± 7.7 preoperatively to 59.8 ± 20.2 postoperatively. The general satisfaction score, on a scale from 0 to 10 (indicating maximum satisfaction), was 1.4 ± 1.6 preoperatively vs. 8.0 ± 2.4 postoperatively. This was one of the few studies that attempted to consistently record the operative time, which was 113.4 ± 21.3 minutes. There was 1 intraoperative fracture (4.3%) that occurred at the level of the humeral metaphysis and was treated with suture. Revision was required in 2 patients (8.7%) and was related to the humeral component in both cases. One patient with instability ultimately underwent revision with polyethylene exchange; the second patient underwent revision to a stemmed Verso prosthesis for a traumatic periprosthetic fracture. No cases of radiolucency, subsidence, or metaphysis osteolysis indicative of stress shielding were noted in this study. Grade 1 scapular notching was noted in 1 patient, with grade 2 noted in another patient, giving a rate of 8.7% (2 of 23).

Micheloni et al (2019) evaluated 19 patients, 7 with osteoarthritis and 12 with acute fractures; the patients with osteoarthritis received the stemless Verso implant, whereas those with acute fractures received the stemmed version. In the stemless group, the average CS improved from 21.57 to 56.86, the average Subjective Shoulder Test score improved from 2.29 to 9.43, and the mean visual analog scale score improved from 14.29 to 4.86; these findings were all statistically significant ($P < .001$). No cases of intraoperative fracture or postoperative dislocation were noted. No findings of subsidence, radiolucent lines around the components, or notching were noted at follow-up.

Quantitative summary of studies

There were 437 total procedures (430 patients), with 272 procedures (266 patients) in the TESS group and 165 procedures (164 patients) in the Verso group. The mean age at the time of surgery was 73.8 years. The age range at the time of surgery was 38-93 years, with 7-98 patients per study and a mean follow-up period of 7-101.6 months per study (Table I). Six studies primarily used the Neviaser-Mackenzie anterosuperior approach, whereas 4 studies used the deltopectoral approach.[50,51] Among the 6 studies that used the anterosuperior approach, the study by Teissier et al[55] used the deltopectoral approach for 4 cases that required concomitant latissimus dorsi transfer. The most common indication was CTA, with 309 cases (70.7%), followed by revision arthroplasty, with 51 cases (11.7%) (Supplementary Tables S1 and S2).

The mean CS at final follow-up was reported and appropriately stratified in 8 studies; the mean CS was 62.7,

Table III Scapular notching by implant

Implant	Total	Rate, %
TESS (n = 165)	30	18.2
Verso (n = 216)	49	22.7

TESS, Total Evolutive Shoulder System.

Table IV Summary of complication and reoperation rates per study

Authors	Total complications, n (%)	Total reoperations, n (%)
Ballas and Beguin[3] (2013)	9 (16)	5 (9)
Kadum et al[33] (2014)	4 (25)	4 (25)
Teissier et al[55] (2015)	3 (3)	1 (1)
Von Engelhardt et al[58] (2015)	2 (4)	1 (2)
Moroder et al[45] (2016)	6 (25)	2 (8)
Levy et al[38] (2016)	14 (14)	6 (6)
Natera et al[47] (2016)	3 (13)	3 (13)
Beck et al[6] (2019)	2 (7)	2 (7)
Leonidou et al[36] (2019)	6 (16)	4 (11)
Micheloni et al[41] (2019)	0 (0)	0 (0)

with a range of 56-68. ROM values demonstrated improvement in all studies that reported preoperative and postoperative data. The weighted average postoperative CS from the TESS studies was 64.3; the weighted average from the Verso studies was 59.9 (Table II).

All studies reported on radiolucency around implants as well as scapular notching at final follow-up (Supplementary Tables S3). The rates of scapular notching ranged from 0% to 72.3%. Ballas and Beguin[3] noted 1 case of significant lysis around the greater tuberosity but without secondary displacement of the humeral cup. Von Engelhardt et al[58] noted loosening of the glenoid component in 3 patients. Moroder et al[45] noted visible bone density loss in 3 patients, but no general loosening was noted. None of the studies noted an association between lower outcome scores and scapular notching (Supplementary Tables S4 and Table III).

Complication rates per study ranged from 0% in the study by Micheloni et al to 25% in the studies by Moroder et al[45] and Kadum et al.[33] Similarly, rates of reoperation ranged from 0% to 25% (Table IV). Intraoperative complications included humeral metaphyseal fractures, glenoid rim fractures, and intraoperative transfusions. The most common postoperative complication was instability/dislocation (Table V).

Discussion

Stemmed humeral implants have been the gold standard for total shoulder arthroplasty for many years.[62] Because of humeral stem–related complications, there has been increased interest in shorter stems, but a paucity of data exists regarding stemless and metaphyseal rTSA.[27] The use of stemless components in aTSA has been proved to be safe and effective when compared with stemmed humeral implants at short-term follow-up.[63]

In both stemless and stemmed rTSA, there can be complications associated with the procedure. The most commonly reported complication is instability with dislocation, with rates ranging from 1.5% to 31%.[13] With stemless humeral components, instability may theoretically be more likely to occur because of more limited options in positioning implant height and complexity in humeral resection owing to the reliance on metaphyseal fixation.[39] There are numerous other complications that can occur including but not limited to periprosthetic fracture, acromial fracture, and scapular notching.[14] In stemless rTSA, patient selection is even more important because of the significant deviation from natural shoulder biomechanics that occurs as a result of the reconstruction.[25] There have also been metaphyseal fractures from excessive impaction with stemless designs reported.[39]

In this review, we evaluated 10 studies that used either the TESS or Verso implant for rTSA and found an overall trend of improved clinical outcome scores, an overall low rate of humeral component loosening of 0.2%, and an overall complication rate of 11.2%. The published complication rate for stemmed primary rTSA is approximately 15%, with rates of up to 40% for revision cases.[4] Reoperation and/or revision rates ranged from 0% to 25% in our review. Only 1 patient within the analyzed studies, who was in the study by von Engelhardt et al,[58] was noted

Table V Incidence of problems and complications

Variable	Cases, n	% of all problems and complications (n = 49)	% of all cases (N = 437)
Intraoperative problems: total	5	10	1.1
Humeral metaphyseal fracture	3	6	0.7
Glenoid rim fracture	1	2	0.2
Intraoperative transfusion	1	2	0.2
Postoperative problems: total	44	90	10.1
Glenoid component dislocation and/or dissociation from baseplate	8	16	1.8
Instability and/or dislocation	11	22	2.5
Superficial infection	1	2	0.2
Deep infection	2*	4	0.5
Hematoma	2	4	0.5
Subscapularis rupture	1	2	0.2
Postoperative stiffness	3	6	0.7
Symptomatic mesacromion	1	2	0.2
Acromial stress fracture	4	8	0.9
Scapular spine fracture	1	2	0.2
Clavicle fracture	1	2	0.2
Periprosthetic glenoid fracture	2	4	0.5
Periprosthetic proximal humeral fracture	6	12	1.4
Unspecified periprosthetic fracture	1	2	0.2

* It is not entirely clear whether the implant was stemless in the case of infection noted in the study by Beck et al[6] (2019).

to have loosening of a stemless humeral component, for an overall humeral loosening rate of 0.2% in this review. Statistical analysis was limited by data-reporting variations, especially the lack of data stratification.[1,3,6,32,33,38,45,55,58] Similarly positive outcomes include the absence of humeral component loosening seen in all studies, with the exception of 1 patient in the study by von Engelhardt et al; the absence of radiolucency, with the exception of 3 patients in the study by Moroder et al[45]; and the statistically significant finding of a decreased operative time (80.5 minutes vs. 109.5 minutes, $P < .001$) with stemless reverse arthroplasty when compared with stemmed reverse arthroplasty, also reported by Moroder et al. The rates of component loosening were low and were similar to those reported for stemmed rTSA.[34] It should be noted that loosening of the glenoid component was observed in 3 patients in the study by von Engelhardt et al, but it is unclear whether this occurred in patients who received a stemless prosthesis or a stemmed prosthesis.

All studies demonstrated statistically significant improvements in outcome scores. The CS was reported in 8 studies, with a mean score of 21.7 preoperatively and 61.9 at the time of final follow-up. In a large retrospective study of patients treated by aTSA for osteoarthritis (n = 505; mean follow-up period, 42.0 months) or rTSA for either osteoarthritis with rotator cuff tear or CTA (n = 678; mean follow-up period, 36.9 months), Simovitch et al[53] reported a postoperative CS of 71.2 in the reverse group, with a mean improvement of 40.1. The mean postoperative CS in the stemless rTSA studies included in our review (69.1) was slightly lower than the CS reported by Simovitch et al in their reverse group. However, the improvement in the CS was greater than that found by Simovitch et al in 3 of the 6 studies in our review that provided both the preoperative CS and postoperative CS. The cases of Beck et al,[6] Levy et al,[38] and Atoun et al[1] demonstrated improvement rates of 47.5, 45, and 43.5, respectively. The QuickDASH score was the next most commonly reported outcome score, with an aggregate mean score at final follow-up of 26 (range, 20-29).[6,33,55] Pain and satisfaction scores were reported with too much variability to provide a conglomerate assessment, but each study that did report pain or satisfaction outcomes showed improvement.[1,3,6,38,55] ROM was similarly significantly improved at final follow-up in each of the studies that provided sufficient data.[1,3,6,33,38,55]

Eight of the ten studies we reviewed provided radiographic results amenable to general analysis.[3,6,32,33,38,45,55,58] Moroder et al[45] detected radiolucency or visible bone loss in 3 patients but observed no radiologic humeral component loosening. Although Kadum et al[32,33] initially detected no radiolucency, they reported 2 cases of glenoid loosening in their 2014 follow-up study. Ballas and Beguin[3] detected 1 case of significant osteolysis of the greater tuberosity without displacement of the humeral component. Teissier et al[55] detected radiolucent lines in the glenoid region in 60.5% of patients, but this did not

appear to affect clinical outcomes. The importance of these radiographic results remains a matter of debate in stemless as well as stemmed rTSA.[24,29] The rates of radiolucent lines in our study varied from 0% to 60.5%, whereas the rates following stemmed rTSA are much lower, with a systematic review by Zumstein et al[65] noting a rate of 2.9% among 782 cases. In a more recent study, Bacle et al[2] found rates as high as 15%. However, no association was found between radiolucencies and poorer outcomes.[2] Furthermore, the low rate of humeral component loosening of 0.2% is more clinically relevant, especially when considering the safety profile of stemless humeral implants.

The clinical significance of scapular notching is unclear, with earlier studies reporting no effect on clinical outcomes and newer studies showing an association with lower postoperative scores.[22,44,60] The studies in our review included data on scapular notching, with Kadum et al[32] reporting rates as low as 0% (mean follow-up period, 14 months) and Beck et al[6] reporting rates as high as 72.3% (mean follow-up period, 101.6 months). We suspect that this broad variation is because of the length of follow-up in the studies.[37]

Limitations of this review include the small number of high-quality studies, lack of data stratification, high risk of bias, and operative technique variation. No randomized controlled trials have been published; only 1 case-control study has been published, which was limited by its small size, stringent criteria, and non-randomization.[45] Some studies did not report preoperative scores, whereas others stratified their data by clinical indication rather than prosthesis configuration. For example, Kadum et al[32] looked at 4 versions of the TESS implant, with only 17 of 49 patients having undergone stemless rTSA, and only reported overall outcome scores. Similarly, von Engelhardt et al[58] looked at patients who received a TESS stemless or stemmed implant for CTA or revision arthroplasty, but they only stratified the results by patient diagnosis, not the implant version. A lack of data also added to a limited interpretation of results. Moroder et al[45] performed a matched case-control study comparing TESS stemless and stemmed rTSA but did not report preoperative clinical scores. Likewise, Teissier et al[55] did not report certain preoperative clinical scores. Nonetheless, an overall trend of improved clinical outcomes can be inferred for all of the studies, and the outcomes are comparable to those after traditional stemmed rTSA.[20,21,54] As the US Food and Drug Administration has not approved stemless rTSA, our study includes only European data. In addition to the TESS prosthesis, there are 2 devices with an investigational device exception for clinical trials in the United States, namely the Easytech device (FX Shoulder USA, Dallas, TX; https://clinicaltrials.gov/ct2/show/NCT03806842) and SMR device (LimaCorporate, San Daniele del Friuli, Italy; https://clinicaltrials.gov/ct2/show/NCT02679352). It should also be noted that some studies were reported by investigators who were designers or co-developers of the implants in the studies, which suggests the possibility of bias. Furthermore, studies completed by the same group reported results that seem to suggest the same cohort of patients was assessed, making summation of data less practical (Table I).

Conclusion

This review shows that the clinical and functional outcomes following stemless and metaphyseal rTSA are quite comparable to those of stemmed implants, especially with the low rate of humeral-sided complications, but there continues to be a need for additional long-term studies and randomized clinical trials. We anticipate that these data will continue to evolve as safety is investigated and implant approval becomes more widespread.

Disclaimer

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Supplementary data

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