



## Current state of short-stem implants in total shoulder arthroplasty: a systematic review of the literature



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**Background:** Humeral stem length in anatomic total shoulder arthroplasty (TSA) continues to decrease in an attempt to preserve bone. Outcomes following short-stem TSA are not well documented. The purpose was to systematically review and report the outcomes and revisions following short-stem humeral implants for TSA.

**Methods:** A systematic review was registered with PROSPERO and performed with PRISMA guidelines using 3 publicly available free databases. Therapeutic clinical outcome investigations reporting TSA outcomes of short-stem implants with levels of evidence I-IV were eligible for inclusion. All study, subject, and surgical technique demographics were analyzed and described.

**Results:** Thirteen studies were included (average follow-up: 33 months, range 24–84 months; 8 studies [62%] were multicenter and 6 [46%] were from Europe). All studies were published in the last 8 years, and almost all (12/13, 92%) reported results of uncemented components. Most of the studies (9/13, 70%) reported results from the Aequalis Ascend or Ascend Flex Stem (Tornier). Improvements were seen in all measured range of motion planes and patient-reported outcome scores. Complications were infrequent, with a 2% humeral loosening rate, a 3% overall revision rate, and a 1% rate of revision for aseptic humeral loosening. Radiographic results showed a 13% rate of radiolucent lines, a 16% rate of condensation lines, and a 22% rate of calcar osteolysis.

**Conclusion:** Short-stem TSA humeral implants provide excellent results, with low revision rates in the short term. Long-term follow-up will be necessary to understand the clinical impact of radiographic calcar osteolysis.

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Total shoulder arthroplasty (TSA) has become an effective treatment for glenohumeral arthritis in patients who have failed nonoperative management and have an intact, functioning rotator cuff. Outcomes following TSA have generally been very encouraging, with significant improvements seen in range of motion and clinical outcome scores.<sup>9,12,13</sup> Unfortunately, despite these overall good results, there are still several complications that can occur in patients undergoing TSA. These complications can be broken

down into intraoperative (fracture of the humerus or glenoid) and postoperative (humeral stem loosening, glenoid loosening, traumatic humeral fracture, dislocation, rotator cuff tears, and others).<sup>1</sup>

In an effort to improve outcomes and mitigate complications, modifications to components used in TSA have occurred on both the glenoid and humeral side over the past 10 years.<sup>17</sup> One of these modifications was to shorten the humeral stem to preserve bone stock and minimize or eliminate some of the complications associated with longer stems, including humeral fracture, bone loss, stem loosening, stress shielding, and others.<sup>1,17,18,20,34</sup> With the shift to shorter stems, many implants also have altered geometries and incorporated porous coatings or grit blasting to improve fixation.

No institutional review board approval was required for this systematic review.

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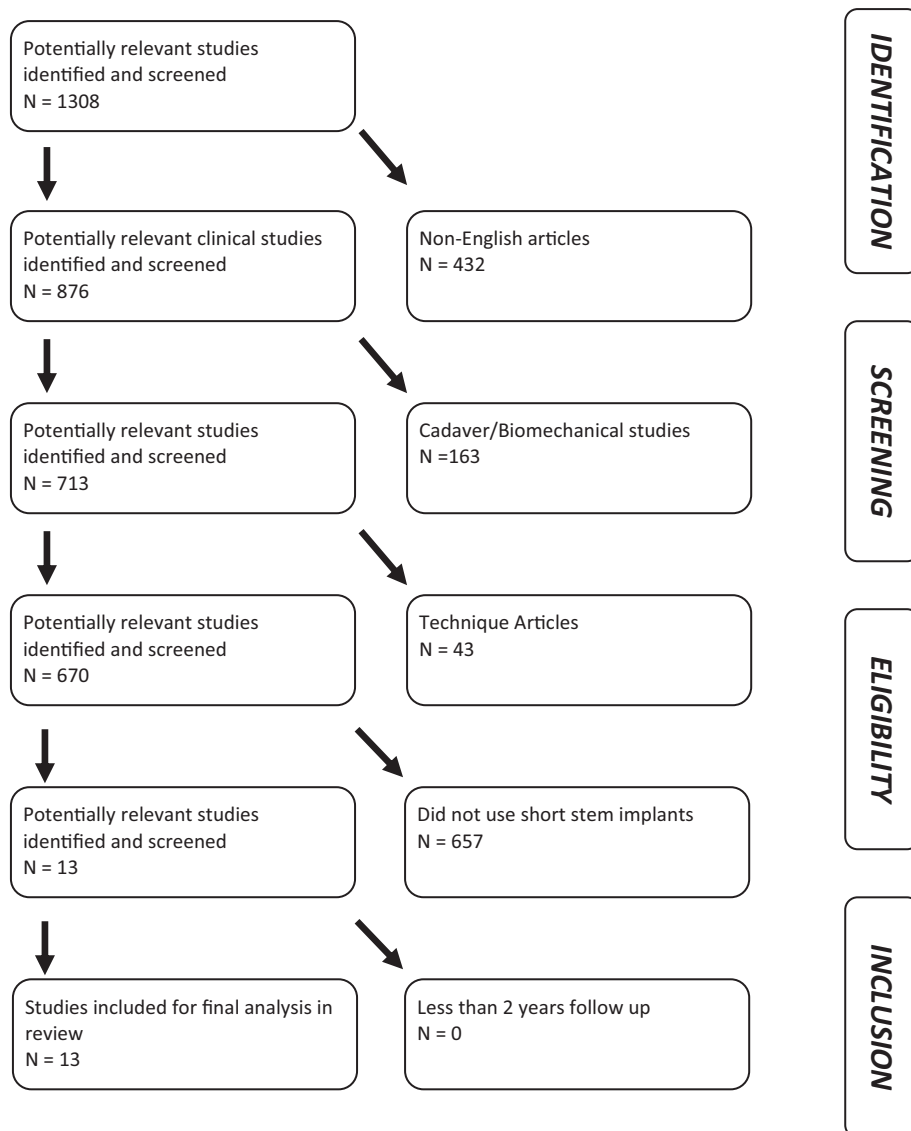
Therefore, the purpose of this study is to systematically review the available English literature and report the clinical and radiographic outcomes as well as revision rates following short-stem humeral implants for TSA. The authors hypothesize that short-stem humeral implants will afford patients excellent clinical outcomes with low revision rates.

**Methods**

A systematic review was conducted according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines using a PRISMA checklist.<sup>25</sup> Systematic review registration was performed using the PROSPERO International prospective register of systematic reviews (CRD42019139086).<sup>38</sup> One author (B.J.E.) independently conducted the search on June 15, 2019, using the following databases: MEDLINE, Cochrane Central Register of Controlled Trials, SportDiscus, and CINAHL. The electronic search algorithm utilized was as follows: (((((((((((((((shoulder) AND arthroplasty) NOT rotator cuff repair) NOT hemiarthroplasty) NOT elbow) NOT knee) NOT thumb) NOT

ankle) NOT wrist) NOT hip) NOT reverse) NOT resurfacing) NOT hand) NOT biomechanics) NOT cadaver). English-language Level I-IV evidence (2011 update by the Oxford Centre for Evidence-Based Medicine<sup>37</sup>) clinical studies with minimum 2 years' follow-up were eligible. Medical conference abstracts were ineligible for inclusion. All references within included studies were cross-referenced for inclusion if missed by the initial search. Duplicate subject publications within separate unique studies were not reported twice. The study with longer follow-up or greater number of subjects was retained for inclusion. Level V evidence reviews, letters to the editor, basic science, biomechanical studies, imaging, surgical technique, and classification studies were excluded.

A total of 1308 studies were located, and after implementation of the inclusion criteria, 13 studies were included in the final analysis (Fig. 1).<sup>2,4,9,10,14,16,27,28,30-33,36</sup> Patients of interest in this systematic review underwent anatomic shoulder arthroplasty and had a minimum 2-year follow-up. Study and subject parameters analyzed included year of publication, years of subject enrollment, presence of study financial conflict of interest, number of subjects and shoulders, sex, age, implant, length of follow-up, treatment of



**Figure 1** PRISMA flowchart. PRISMA, Preferred Reporting Items for Systematic reviews and Meta-Analyses.

the subscapularis, and range of motion. Radiographic outcomes including dislocation, loose humeral component, humeral component at risk for loosening, humeral component radiolucent lines, humeral component condensation lines, and calcar osteolysis were recorded as were complications as per the manuscripts. Clinical outcome scores recorded included the Disabilities of the Arm, Shoulder, and Hand, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form (ASES), Constant score, visual analog scale, Simple Shoulder Test, Single Assessment Numerical Evaluation, University of California Los Angeles (UCLA) Shoulder Score, and Subjective Shoulder Value. Study methodological quality was evaluated using the Modified Coleman Methodology Score.<sup>6</sup>

### Statistical analysis

To avoid excess bias for any single study, we did not perform any grouped analysis for variables in which fewer than 3 studies reported any single variable. For categorical variables, pooling was performed across studies to determine overall complication rates. For continuous variables, weighted means and standard deviations were calculated. All analyses were conducted in Excel X (Microsoft, Redmond, WA, USA) and SPSS, version 25 (IBM, Armonk, NY, USA).

### Results

Of the 13 studies included, most (11/13, 85%) authors reported a relevant conflict of interest (Table I). Most studies were Level III or IV (12/13, 92%) multicenter (8/13, 62%) studies, with a relatively even split between Europe (6/13, 46%) and North America (7/13, 54%). Most results were short-term, with a minimum of 2 years' follow-up and a weighed mean of 33 months' follow-up (range 24–84 months). Demographics are reported in Table I. All studies were published in the last 8 years and almost all (12/13, 92%) reported results of uncemented components. Most of the studies (9/13, 70%) reported results from the Aequalis Ascend or Ascend Flex Stem (Tornier, Memphis, TN, USA).

The following variables were not analyzed because fewer than 3 studies reported them: the Disabilities of the Arm, Shoulder, and Hand score, the UCLA Shoulder Score, the Subjective Shoulder Value score, and operative time. Improvements were seen in all measured range of motion planes and patient-reported outcome scores (Table II). Complications were infrequent, with a 2% humeral loosening rate, a 3% overall revision rate, and a 1% rate of revision for aseptic humeral loosening (Table III). However, radiographic results were concerning, with a 13% rate of radiolucent lines, a 16% rate of condensation lines, and a 22% rate of calcar osteolysis.

### Discussion

Anatomic TSA is an effective treatment for patients with glenohumeral arthritis. This study found excellent results following TSA using short-stem implants, with a low revision rate. There were, however, some concerning radiographic findings of unknown clinical significance.

Although results following TSA are generally good, complications, although infrequent, can be a significant cause of pain and disability to these patients. One of the complications from TSA, either intraoperatively or postoperatively, is a periprosthetic humerus fracture.<sup>15,40</sup> The literature reports the incidence of intraoperative humeral fractures in TSA to be approximately 1.5%, whereas the incidence of postoperative periprosthetic humeral fracture following TSA is between 0.7% and 2.3%.<sup>1,20,34</sup> No patients included in this study sustained an intraoperative humerus

**Table I**

Characteristics of the 13 included studies and patients

Variable	% (n/N) or mean ± SD
Conflict of interest	
Conflict present	85 (11/13)
Conflict not present	15 (2/13)
Level of evidence	
II	8 (1/13)
III	38 (5/13)
IV	54 (7/13)
Single-center	38 (5/13)
Continent of origin	
Europe	46 (6/13)
North America	54 (7/13)
Age, yr, mean ±SD	67 ± 2
Sex	
Male	50 (277/557)
Female	50 (280/557)
Minimum length of follow-up	
24 mo	77 (10/13)
49 mo	8 (1/13)
Not reported	16 (2/13)
Cemented humeral component	8 (1/13)
Length of follow-up, mo, mean ±SD	33 ± 10
Year of publication	
2011	8 (1/13)
2013	8 (1/13)
2015	8 (1/13)
2016	16 (2/13)
2017	16 (2/13)
2018	38 (5/13)
2019	8 (1/13)
Prostheses examined	
Affinis (Mathys*)	8 (1/13)
Aequalis Ascend or Ascend Flex (Tornier)	70 (9/13)
Apex (Arthrex <sup>†</sup> )	16 (2/13)
Comprehensive Micro (Biomet <sup>‡</sup> )	8 (1/13)
Subscapularis management	
Peel	25 (209/833)
Lesser tuberosity osteotomy	20 (170/833)
Tenotomy	29 (241/833)
Not described	26 (213/833)

SD, standard deviation.

\* Mathys (Bettlach, Switzerland).

<sup>†</sup> Arthrex (Naples, FL, USA).

<sup>‡</sup> Biomet (Warsaw, IN, USA).

fracture. This is likely a result of less aggressive reaming and broaching techniques and new, concerted efforts not to oversize the stem with short-stem implants. Interestingly, the radiographic results did not mention any significant number of implants placed in malalignment, specifically in varus, which is one of the concerns with the short stem. Meticulous surgical technique of avoiding

**Table II**

Weighted-average results

Variable	Preoperative	Postoperative	Change
Active forward elevation	99° ± 15°	147° ± 17°	49° ± 19°
Abduction	80° ± 12°	141° ± 21°	61° ± 19°
Active external rotation	19° ± 11°	48° ± 9°	30° ± 9°
ASES score	39 ± 3	85 ± 3	46 ± 2
Constant score	30 ± 5	74 ± 11	42 ± 11
VAS score	5.7 ± 0.7	1.3 ± 0.4	-4.4 ± 0.7
SST score	4 ± 0.1	9.8 ± 0.2	5.8 ± 0.2
SANE score	34 ± 3	81 ± 6	47 ± 5

ASES, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form; VAS, visual analog scale for pain; SST, Simple Shoulder Test; SANE, Single Assessment Numeric Evaluation.

Concerning range of motion data, forward flexion was reported in 12/13 studies, abduction in 7/13 studies, and external rotation in 12/13 studies. Concerning clinical outcome scores, ASES was reported in 6/13 studies, Constant in 7/13 studies, VAS in 5/13 studies, SST in 3/13 studies, and SANE in 5/13 studies.

**Table III**  
Pooled complication rates among the 13 included studies (N=823 shoulders)

Category	n (%)
Dislocation	3 (0.4)
Loose humeral component	16 (1.9)
Humeral component at risk for loosening	21 (2.5)
Humeral component radiolucent lines	108 (13.0)
Humeral component condensation lines	133 (16.0)
Calcar osteolysis	187 (22.4)
Hematoma	3 (0.4)
Infection	2 (0.2)
Revision surgery	24 (2.9)
Revision for aseptic humeral loosening	8 (1.0)
Revision for septic humeral loosening	6 (0.7)
Revision for fracture	1 (0.1)
Revision for glenoid loosening	1 (0.1)
Revision for dislocations	2 (0.2)
Revision for stiffness	1 (0.1)
Revision for distal clavicle excision	1 (0.1)
Revision for subscapularis repair failure	2 (0.2)
Revision for conversions to RTSA for rotator cuff tear	3 (0.4)

RTSA, reverse total shoulder arthroplasty.

oversizing the implant and avoiding placing the implant in varus can help optimize a patient's outcomes following TSA with a short-stem implant.<sup>10,32</sup>

A second complication, although uncommon, that can occur following TSA is loosening of the humeral stem.<sup>17</sup> Although loosening of the glenoid is a much more common complication, loosening of the humeral stem too can occur. The United States Food and Drug Administration—mandated Manufacturer and User Facility Device Experience database released a report regarding the causes of failure following TSA and found that loosening of the humeral stem made up 5.8% of all complications following TSA (problems with the glenoid were significantly more common and accounted for 20.4% of the failures).<sup>35</sup> Of all the patients included in this study, only 2% developed loosening of the humeral stem, which is similar to previous reports on longer-stem implants.<sup>5</sup> Furthermore, despite a low rate of humeral component loosening, there was a 22.7% rate of calcar osteolysis in this study on short humeral stems. Prior studies have reported calcar osteolysis rates of 31% at 2 years and up to 64% at 4 years in traditional-length stems.<sup>9,11</sup> However, to date, there has not been a clear correlation between calcar osteolysis and symptomatic humeral loosening. Although the radiographic feature is concerning, it is unclear how clinically relevant this finding is from a functional perspective. The decreased humeral stem loosening rate, but significant amount of calcar osteolysis, with short-stem implants may be related to newer implant designs with grit blasting or porous coating leading to improved bony ingrowth.<sup>28,39</sup> This could also be due to improved techniques used in prior studies on long-stem components, translated to short-stem components on implantation of the humeral stem by impaction bone grafting of any concerning areas proximally.<sup>7,26</sup> Finally, this decreased loosening rate could be due to improved management of the subscapularis, which can afford improved mechanics and stability to the humerus.<sup>3,8,21</sup>

It is unclear what the ideal management of the subscapularis is when performing a TSA (peel, tenotomy, lesser tuberosity osteotomy [LTO]).<sup>21,22</sup> Most of the studies in the literature comparing subscapularis peel to LTO were performed in traditional-length humeral implants, although the results are equivalent between techniques.<sup>21,22,24</sup> With shorter stem and now stemless implants, there is potentially less room for error when performing an LTO, as taking a deep chunk of bone from the lesser tuberosity runs the risk of compromising fixation proximally for the humeral stem (a wafer osteotomy does not have this risk).<sup>23</sup> As there is no distal fixation in short-stem implants, this can pose a problem in short-stem

implants and requires a meticulous surgical technique, although no high-quality studies have evaluated this to date. This could be one of the reasons only 20% of patients included in this review underwent an LTO compared with 54% who underwent soft tissue subscapularis management with either a peel or tenotomy. Regardless, subscapularis tenotomy and peel were more common in patients undergoing short-stem TSA in this study than LTO. Similar concerns, only potentially amplified, could extend to stemless devices.

Although the loosening rate in this study was low, there were some concerning radiographic findings reported, including calcar osteolysis, condensation lines, and radiolucent lines. These findings are consistent with prior studies of both short- and long-stem implants, although the clinical significance of these findings remains unclear. Raiss et al<sup>29</sup> reported on a series of 67 press-fit (noncemented) short-stem implants with a 5.5-year follow-up and found that 57% of patients demonstrated a radiographic radiolucent line. However, none of these patients required a revision for aseptic loosening of the humeral stem. Similarly, Khan et al<sup>19</sup> reported 10-year follow-up on 39 shoulders with cemented humeral stems and found a radiolucent line in 50% of patients. Consistent with the prior study, no patients necessitated a revision for aseptic humeral loosening. Hence, the clinical significance of the radiographic findings seen in this study remain unknown and may be of no clinical consequence. Longer-term outcome studies are necessary to determine if these radiographic changes are simply adaptive, if they become pathologic and require treatment, or if they will complicate future revisions.

#### Limitations

This study is a review of the literature of mostly Level III and IV studies, and as such is subject to the limitations of each individual study. Although this study reported outcomes on short-stem implants with minimum 2 years' follow-up, it did not directly compare these results to long-stem implants as a great deal of heterogeneity exists in the literature regarding long-stem implants. Many of the patients included in this study were operated on by high-volume, experienced shoulder surgeons, so it is possible the results are not translatable to all orthopedic surgeons who perform shoulder arthroplasty. Studies reported radiographic outcomes based on their own criteria to determine loosening, components at risk, etc. Therefore, it is possible that variation exists in this area between studies. Furthermore, the average length of follow-up for all patients included in this study was just over 30 months. Longer-term follow-up studies are necessary to follow the radiographic changes reported in these studies to understand if these become clinically significant or remain clinically silent.

#### Conclusion

Short-stem TSA humeral implants provide excellent results with low revision rates in the short term. Long-term follow-up will be necessary to understand the clinical impact of radiographic calcar osteolysis.

#### Disclaimer

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## Supplementary Data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jses.2019.10.112>.

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