JSES International 6 (2022) 802–808

Contents lists available at ScienceDirect

JSES International

journal homepage: www.jsesinternational.org

A 135° short inlay humeral stem leads to comparable radiographic and clinical outcomes compared with a standard-length stem for reverse shoulder arthroplasty

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A R T I C L E I N F O

Keywords:
Reverse total shoulder arthroplasty (RTSA)
Radiograph
Short stem
Loosening
Humeral component
Outcome

Level of evidence: Level III; Retrospective Cohort Comparison; Treatment Study

Background: Humeral stem length in reverse total shoulder arthroplasty (RTSA) has decreased in recent years in an attempt to preserve more bone and facilitate stem removal in the revision setting. The purpose of this study was to compare the clinical and radiographic outcomes of a short- to standard-length stem RTSA. The authors hypothesized that there would be no difference in radiographic or clinical outcomes at short-term follow-up.
Methods: Patients who underwent RTSA using a press-fit standard- or short-length humeral component with a consistent geometry (Univers Revers, or Revers Apex; Arthrex, Inc., Naples, FL, USA) were evaluated in a multicenter retrospective review. The minimum clinical follow-up was 2 years. Immediate postoperative radiographs were used to assess initial alignment and filling ratios. In addition, radiographs at 2 years were evaluated for signs of stress shielding and/or loosening. Clinical outcome scores and range of motion were evaluated at the final follow-up and compared between groups.
Results: A total of 220 patients with short-stem RTSA and 357 patients with standard-length stem RTSA were analyzed. There was no difference in baseline function between short- and standard-length stem patients. Patients in the short stem group had higher postoperative American Shoulder and Elbow Surgeons (84.6 vs. 80.8; $P = .014$) and Western Ontario Osteoarthritis of the Shoulder (86.5 vs. 82.7; $P = .025$). Patients in the short stem group also had greater postoperative active forward flexion (139° vs. 132°; $P = .003$) and internal rotation with the arm at 90° of abduction (43° vs. 32°; $P < .001$) than patients in the standard-length group. Radiographically, there was a higher metaphyseal ($P = .049$) and diaphyseal ($P < .001$) fill ratio in the short stem group, although there was no difference in postoperative alignment, radiographic signs of loosening, or revision for loosening between groups (all $P > .05$).
Conclusion: A short inlay stem leads to comparable radiographic findings and revision-free survival compared with a standard-length stem when placed with a press-fit technique for RTSA. Clinical outcomes are also equivalent or slightly improved with a short stem compared with a standard-length stem.

Reverse total shoulder arthroplasty (RTSA) is an effective treatment option for patients with rotator cuff tear arthropathy, glenohumeral arthritis with significant deformity, and many other shoulder conditions.[7,10,14,16] Although results after RTSA are good, there are still patients who require a revision surgery for infection, fracture, instability, etc. One of the problems with revision shoulder surgery in the setting of an RTSA is loss of humeral bone stock.[2]

This study was approved by the Southern Oregon Institutional Review Board. Investigation performed at Rothman Orthopaedic Institute, New York, NY.
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https://doi.org/10.1016/j.jseint.2022.05.003
2666-6383/

Removing a well-fixed standard-length stem can be quite challenging and can be very traumatic to the humeral bone.

Over time, modifications have been made to the glenoid and humeral components to improve the accuracy of implantation, reduce trauma, and increase fixation.[13] A recent modification to some humeral stems was to shorten the length of the stem by several centimeters.[1,3] A shorter humeral stem theoretically allows for preservation of humeral bone stock, which can be extremely beneficial in the setting of revision RTSA.[4] However, as this is a relatively recent modification, the clinical outcomes of short humeral stems, specifically inlay humeral prostheses, have not been well defined, particularly for RTSA.[8] To date, no results to our knowledge have been published specifically using a 135° inlay short stem. Furthermore, it is unclear if short humeral stems have a higher rate of placement in varus/valgus, have higher rates of stress shielding, higher risk of subsidence, or higher risk of loosening compared with standard-length stems.

Therefore, the purpose of this study was to compare the 2-year clinical outcomes after RTSA with a short- or standard-length inlay humeral stem. A secondary purpose was to compare the initial postoperative radiographs as well as radiographic outcomes at 2 years based on stem length. The authors hypothesized that there would be no significant difference in clinical or radiographic outcomes based on stem length and that there would be a similar rate of radiographic anatomic alignment between short and long stems, but that metaphyseal filling ratios would be higher with the use of short stem.

Methods

A retrospective review was performed of patients who underwent RTSA with a press-fit humeral component between 2015 and 2019 and were enrolled in prospective multicenter study of 14 sites with 15 surgeons. Inclusion criteria were (1) primary arthroplasty, (2) press-fit fixation, and (3) minimum clinical follow-up of 2 years. Exclusion criteria were (1) RTSA as a treatment for acute fracture, (2) revision arthroplasty, (3) the use of cement for humeral stem fixation, and (4) incomplete follow-up. Institutional review board approval was obtained before initiating the prospective registry, and all patients consented to participation at the time of enrollment.

All RTSA were performed with a press-fit humeral stem that is calcium phosphate (CaP) coated of identical geometry, which consists of an inlay humeral cup and with grit-blasting and a medial-lateral flare that is partially grit blasted and used to obtain fixation at the level of the calcar (Univers Revers; Arthrex Naples, FL, USA). The short stem (Revers Apex) measures 60-65 mm in length (Fig. 1*A*). The standard-length stem (Univers Revers) measures 111-147 mm in length (Fig. 1*B*). Although the cup is modular and allows for either a 155° or 135° humeral inclination angle, all patients in this study were implanted with a 135° configuration.

This was a multicenter study. All surgeries were performed through a deltopectoral approach. Stem length was based on surgeon preference and sizing. The short stem became available in September of 2018, so before that period, only standard-length stems were available. After standard circumferential exposure and reaming of the glenoid was complete, a baseplate was then placed (Universal Glenoid or Modular Glenoid Baseplate; Arthrex, Inc., Naples, FL, USA). Based on patient pathoanatomy, surgeon preference, and soft tissue tension, a neutral or lateralized baseplate (0, 2, or 4 mm of lateralization) was chosen and either a 0- or 4-mm lateralized glenosphere of appropriate diameter was then impacted. Glenosphere diameters ranged from 33 to 42 mm in increments of 3 mm.

Figure 1 (**A**) Image demonstrating the short stem press-fit humeral component, Revers Apex (Arthrex, Naples FL, USA). (**B**) Image demonstrating the standard-length stem press-fit humeral component, Univers Revers (Arthrex, Naples FL, USA).

Clinical evaluation

Preoperative and postoperative clinical outcome scores were recorded for all patients. These scores included the American Shoulder and Elbow Surgeons (ASES), visual analog scale, Western Ontario Arthritis of the Shoulder Index (WOOS), and Single Assessment Numeric Evaluation. Range of motion (ROM) was also recorded at baseline and at 2-year follow-up for forward flexion (FF), internal rotation (IR) with the arm at 90° of abduction, and external rotation (ER) with the arm at the side.

Radiographic evaluation

Grashey and axillary radiographic images from the immediate postoperative visit (within 6 weeks of surgery) and final follow-up visit (minimum 2 years) were reviewed by 2 authors (BJE and TW) to determine the initial implant alignment (Figs. 2-4), metaphyseal and diaphyseal filling ratios (Fig. 5), incidence of radiolucent lines, cortical thinning, condensation lines, proximal stress shielding, calcar osteolysis, any subsidence or shift in component position and implant loosening.[1,6] Initial implant alignment was classified as neutral (between 130° and 140°), valgus (>140°), or varus (<130°).[1] Radiolucent lines and cortical thinning in the short-stem cohort were assessed using the zones previously described by Schnetzke et al.[15] Radiolucent zone size was evaluated using the scale

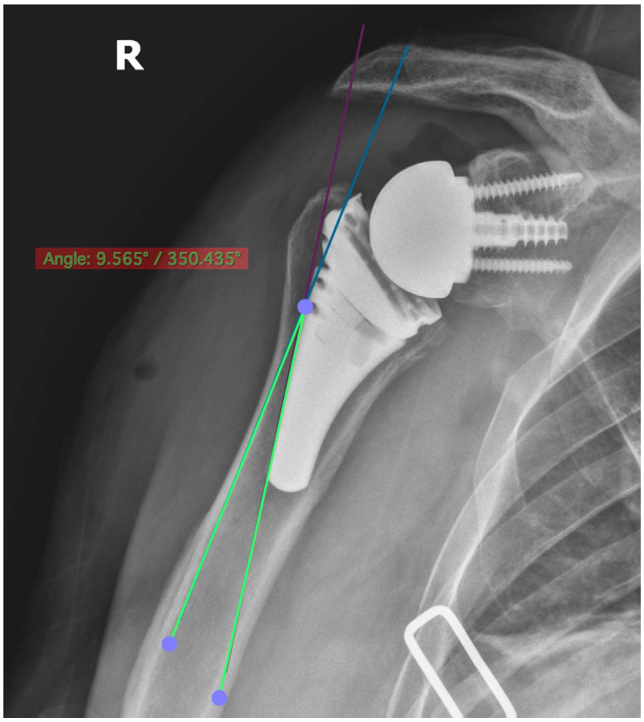

Figure 2 Initial postoperative radiograph demonstrating a stem that was placed into valgus alignment. Note the difference of more than 9° between the alignment of the prosthesis and humerus.

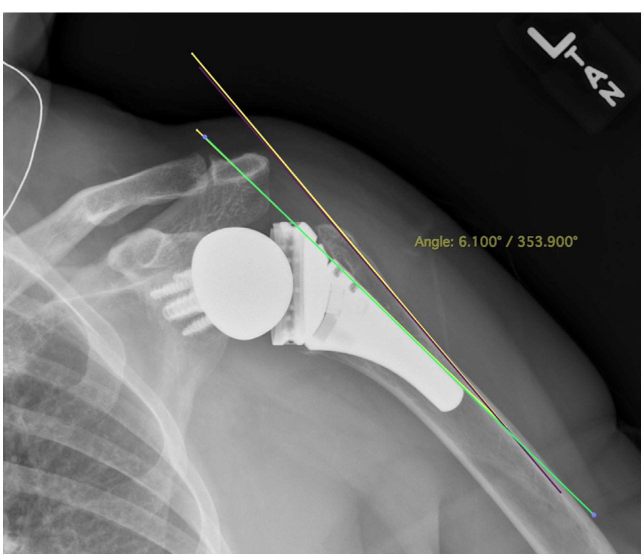

Figure 3 Initial postoperative radiograph demonstrating a stem that was placed into varus alignment. Note the difference of more than 6° between the alignment of the prosthesis and humerus.

previously described by Casagrande et al.[5] Each patient was classified as having a "low" or "high" number of zones with cortical thinning. A "low" classification was given to patients with 3 or less zones that showed cortical thinning, whereas a "high" score was given to those with 4 or more zones of cortical thinning.

Statistics

Continuous data were described by mean and standard deviations. Categorical data were presented as a number and

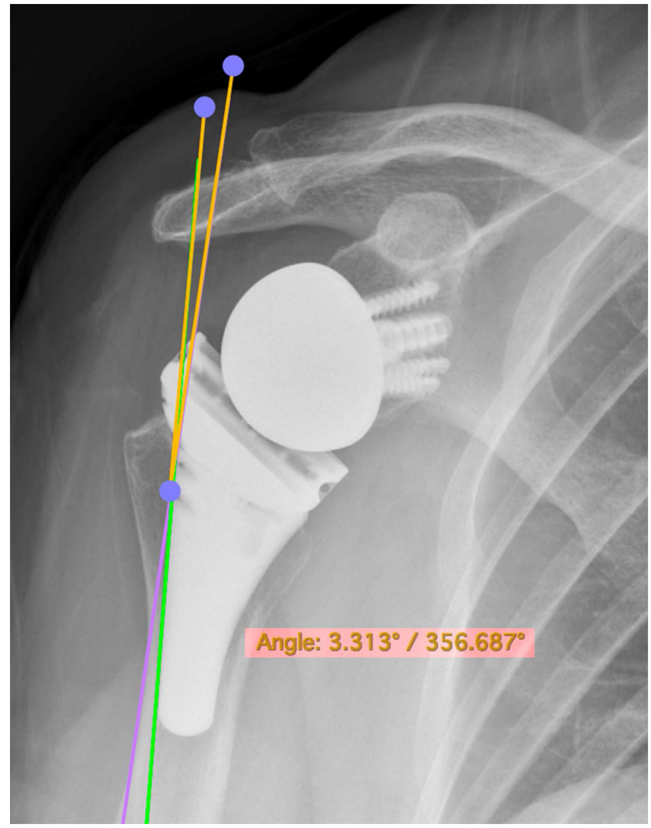

Figure 4 Initial postoperative radiograph demonstrating a stem that was placed into neutral alignment. Note the difference of less than 5° between the alignment of the prosthesis and humerus. The varus/valgus is calculated by drawing a line that is in line with the lateral aspect of the implant and a separate line that goes along the lateral border of the humerus. The angle between these 2 lines is the amount of varus/valgus that the implant is in.

percentage. Comparisons of continuous data were made with a Student's *t*-test. Comparisons of categorical variables were performed with chi-squared tests or Fisher's exact tests for small sample sizes. Additional subgroup analysis comparing radiographic and clinical outcomes by initial stem alignment (neutral, varus, and valgus) was performed using one-way analysis of variance for continuous variables with a Tukey's post hoc test, and multiple chi-squared analyses for categorical variables. Finally, the effect of metaphyseal and diaphyseal filling ratios on radiographic adaptive humeral changes was investigated for both stems using logistic regression analyses where the dependent variable was the adaptive change, and independent variables were the filling ratios, age, sex, body mass index, and tobacco use. For all statistical comparisons, $P < .05$ was considered significant. All analysis was performed in SPSS version 27 (IBM, Armonk, NY, USA)

Results

A total 383 patients had a short-stem RSA during the study period. Seven patients (1.8%) underwent revision before 2 years postoperatively for the following indications: glenoid loosening (n = 2, 0.5%), instability/dislocation (n = 3, 0.8%), periprosthetic fracture (n = 1, 0.3%), and humeral loosening (n = 1, 0.3%). Clinical follow-up at a minimum of 2 years postoperative was available for 220 of the remaining 376 patients (58.5%). Of these, 91 patients had complete radiographs available for the radiographic analysis.

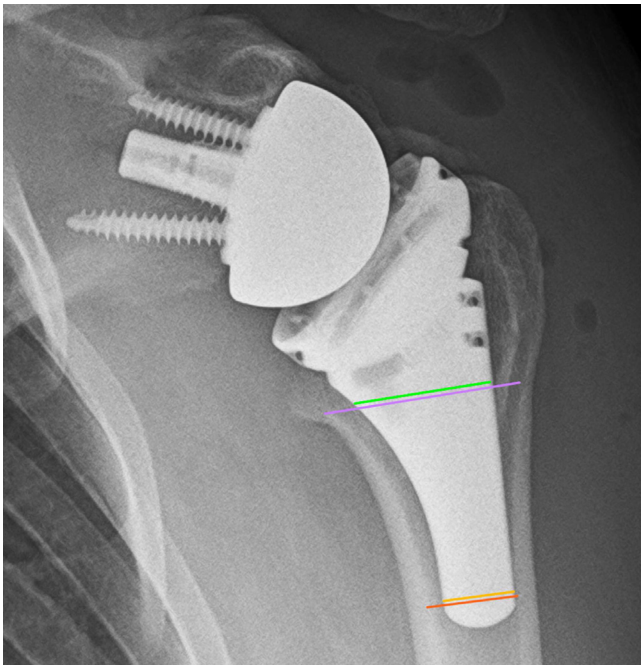

Figure 5 Measurements of metaphyseal and diaphyseal filling ratios. Metaphyseal filling ratio was calculated by dividing the metaphyseal length of the stem (*green line*) by the length of the metaphyseal bone (*purple line*). The diaphyseal filling ratio was calculated by dividing the diaphyseal length of the stem (*orange line*) by the length of the diaphyseal bone (*red line*).

A total of 561 patients had a standard-length stem RSA between during the study period. Twelve patients (2.1%) underwent revision before 2 years postoperative for the following indications: glenoid loosening (n = 3, 0.5%), instability/dislocation (n = 4, 0.7%), periprosthetic fracture (n = 1, 0.2%), humeral loosening (n = 1, 0.2%), and infection (n = 3, 0.5%). Clinical follow-up at a minimum of 2 years postoperative was available for 357 of the remaining 549 patients (65.1%). Of these, 153 patients had complete radiographs available for the radiographic analysis.

Baseline demographic characteristics were similar between the short- and standard-length stem groups, with the exception that there was a higher percentage of males in the short stem group (Table I). Baseline outcome scores and ROM were similar between groups except for FF, which was significantly greater in the standard-length stem group.

Clinical outcomes and ROM

At 2-year follow-up, patients in the short stem group had significantly better ASES scores and significantly better WOOS scores compared with the standard-length stem group (Table II). Patients in the short stem group had significantly more active FF and IR with the arm at 90° of abduction compared with the standard-length stem group.

Radiographs

On initial postoperative radiographs, there was a greater metaphyseal and diaphyseal fill ratio in the short stem group compared with the standard-length stem group (Table III). No difference was seen in the initial alignment between groups. When comparing radiographs at a minimum 2-year follow-up, there were no significant differences in any of the measured variables.

Complications and revisions

Among patients with complete follow-up, revision for humeral loosening was required for one short stem (0.4%; 1/227) and one standard-length stem (0.3%; 1/369). A periprosthetic fracture requiring stem revision occurred in one short stem (0.4%, 1/227 and 0.3%, 1/369). There were 3 infections in the standard-length stem group requiring component removal (0.8%, 3/369). Thus, the revision-free survival related to humeral complications was 98.8%, including 99.2% in the short stem group and 98.7% in the standard-length stem group.

Discussion

The primary finding of this study was that a short inlay press-fit humeral stem led to comparable clinical outcomes compared with standard-length humeral stem at minimum 2-year follow-up of RTSA. Furthermore, there were similar rates of radiographic alignment and initial postoperative radiographic findings between short- and standard-length stems. These data provide support for the adoption of short stem RTSA when appropriate.

Although short stem and stemless humeral components have been extensively studied in anatomic total shoulder arthroplasty, there has been much less data reported on the radiographic outcomes of short-stem humeral prostheses in RTSA.[3,9] Although there may be several benefits to a shorter humeral stem, it is important to understand if these benefits come at the expense of fixation or increased stress shielding. In the present study, there were no differences in the rate of stress shielding or risk for loosening between the short- and standard-length stem groups. This low rate of radiographic changes in the short stem group may have been due to the filling ratios of the short stem group as the stem is not fixed distally as it is for the standard-length stem. Raiss et al reviewed radiographs of 77 patients who underwent RTSA with a short stem humeral component.[14] The authors found that patients with few radiographic changes had a metaphyseal filling ratio of 68%, whereas patients with many radiographic changes had a filling ratio of 74%. In the present study, the average metaphyseal filling ratio was 66% in the short stem and 64% in the standard-length stem groups and may have contributed to the low number of radiographic changes. Interestingly, Raiss et al also found that patients with several radiographic changes had a high diaphyseal filling ratio (85%) compared with a lower filling ratio (77%) in the group with few radiographic changes. Both of these diaphyseal filling ratios were higher than what was seen in the present study of 58% in the short stem group and 35% in the long stem group. Based on the results of the present study and the study by Raiss, there may be an ideal metaphyseal (around 60%-70%) filling ratio to minimize stress shielding, but either short- or standard-length stems can be used to adequately achieve press-fit fixation during RTSA.

Another important finding from the present study was the high number of short stems that were placed in neutral alignment (within 5° of the neck-shaft angle of the prosthesis; 95.6%), indicating excellent initial postoperative alignment. The alignment did not change at the 2-year follow-up mark for the cohort of patients with 2-year radiographs. Ladermann reported the initial alignment of a short stem humeral prothesis with an oval proximal design in 157 patients and found 47% of the humeral stems were placed into varus or valgus.[12] This difference may have been related to stem design or may have been related to differences in surgical approach. A recent study by Abdic et al reported on the radiographs of 124 patients who underwent RTSA with an uncemented curved short stem with a 145° neck-shaft angle.[1] Similar to the present study, the authors defined the implants as neutral if the value fell within ±5°

Table I
Baseline characteristics of patients.

Variable	Apex RTSA (n = 220)	Univers RTSA (n = 357)	P value
Patient demographics			
Age (years), mean (SD)	68.5 (8.6)	69.4 (7.4)	.183
Sex (male), n (%)	134 (60.9)	161 (45.1)	**<.001**
BMI (kg/m^2), mean (SD)	30.3 (5.6)	30.8 (7.3)	.385
Dominant arm (yes), n (%)	125 (56.8)	208 (58.3)	.733
Tobacco use (yes), n (%)	13 (5.9)	24 (6.7)	.698
Diabetes (yes), n (%)	33 (15.0)	36 (10.1)	.077
Implant variables			
Glenosphere diameter			
33 mm, n (%)	33 (15.0)	29 (8.1)	**.010**
36 mm, n (%)	43 (19.5)	186 (52.1)	**<.001**
39 mm, n (%)	100 (45.5)	77 (21.6)	**<.001**
42 mm, n (%)	44 (20.0)	65 (18.2)	.593
Glenoid metallic lateralization, n (%)			
0 mm	8 (3.6)	44.0 (12.3)	**<.001**
2 mm	8 (3.6)	3.0 (0.8)	**.017**
4 mm	49 (22.3)	240.0 (67.2)	**<.001**
6 mm	92 (41.8)	49.0 (13.7)	**<.001**
8 mm	63 (28.6)	21.0 (5.9)	**<.001**
Stem size, mean (SD)	9 (2)	7 (2)	**<.001**
Baseline PROs and ROM, mean (SD)			
VAS pain	5.4 (2.7)	5.8 (2.5)	.071
ASES	41.2 (18.2)	38.5 (17.9)	.081
WOOS	37.3 (18.4)	36.6 (18.9)	.662
SANE	30.4 (20.4)	31.5 (24.1)	.573
VR-12 mental	49.6 (11.6)	49.3 (12.6)	.775
Active FF (degrees)	89 (36)	96 (37)	**.026**
Active ER at side (degrees)	26 (21)	28 (21)	.267
Active IR (at 90 abd)	21 (23)	21 (24)	1.000

RTSA, reverse total shoulder arthroplasty; *SD*, standard deviation; *BMI*, body mass index; *PRO*, patient-reported outcomes; *ROM*, range of motion; *VAS*, visual analog scale; *ASES*, American Shoulder and Elbow Surgeons; *WOOS*, Western Ontario Osteoarthritis of the Shoulder; *SANE*, Single Assessment Numeric Evaluation; *FF*, forward flexion; *ER*, external rotation; *IR*, internal rotation.
Bold font indicates a statistically significant difference.

Table II
Clinical outcomes.

Variable	Apex RTSA (n = 220)		Univers RTSA (n = 357)		P value
2 years	Mean	SD	Mean	SD	
VAS pain	1.0	2.0	1.2	2.1	.258
ASES	84.6	16.7	80.8	18.7	**.014**
WOOS	86.5	18.3	82.7	20.5	**.025**
SANE	76.6	24.8	73.9	24.7	.203
VR-12 mental	53.5	8.9	53.2	9.2	.700
Active FF (degrees)	139	21	132	30	**.003**
Active ER at side (degrees)	46	15	45	21	.538
Active IR (at 90 abd)	43	20	32	18	**<.001**

RTSA, reverse total shoulder arthroplasty; *SD*, standard deviation; *VAS*, visual analog scale; *ASES*, American Shoulder and Elbow Surgeons; *WOOS*, Western Ontario Osteoarthritis of the Shoulder; *SANE*, Single Assessment Numeric Evaluation; *FF*, forward flexion; *ER*, external rotation; *IR*, internal rotation.
Bold font indicates a statistically significant difference.

of the longitudinal humeral axis. The authors found that 73% of stems were placed in neutral alignment, whereas 22% were in valgus and 5% were in varus. The average metaphyseal and diaphyseal filling ratios were 68% and 72%, respectively, of which the diaphyseal filling ratio was much higher than in our study. The authors found a low positive association between stem diameter and filling ratios where they noted that smaller stem sizes were more likely to be placed in varus or valgus, which may be related to stem design. The results of our study showed a higher percentage of stems placed in neutral alignment, which may be due to the design of the prothesis in our series, which has a medial-lateral taper that fills proximally and thus facilitates alignment, as it was not because of higher filling ratios.

Recent evidence has supported the results of the present study that patients who undergo RTSA with a short stem humeral component also do well from a functional perspective. Giuseffi et al reported on 44 patients (29 females and average age 76 years) who underwent primary RTSA with a short uncemented humeral stem.[9] At an average follow-up of 27 months, the authors reported that 43 shoulders (97.7%) rated their pain as "none" or "mild." They noted a significant improvement in active elevation and external rotation, and using the Neer score to report clinical outcomes, the authors found the score was excellent in 27 (61.3%), satisfactory in 15 (34.1%), and unsatisfactory in 2 (4.5%). Atoun et al performed a similar study, reporting the outcomes of 31 patients who underwent RTSA with a short stem humeral component and noted significant improvements in clinical outcomes with no radiographic signs of loosening at an average of 3-years follow-up.[3] They did, however, report 5 late traumatic humeral fractures that all required revision surgery. These results are consistent with the present study as significant improvements in pain and function were seen in the short stem group at early follow-up. Although improvements

Table III
Radiographic findings.

Variable	Apex RTSA (n = 91)		Univers RTSA (n = 153)		*P* value
Immediate postoperative positioning/fill	Mean	SD	Mean	SD	
Neck-shaft angle	135	3	136	3	**.012**
Metaphyseal fill ratio	66%	7%	64%	8%	**.049**
Diaphyseal fill ratio	58%	31%	35%	16%	**<.001**
Alignment	n	%	n	%	
Neutral	86	94.5	139	90.8	.303
Valgus	1	1.1	7	4.6	.140
Varus	4	4.4	7	4.6	.948
2-year postoperative radiographic outcomes	n	%	n	%	
Scapular notching	26	28.6	44	28.8	.975
Calcar osteolysis	5	5.5	17	11.1	.139
Greater tuberosity resorption	4	4.4	8	5.2	.771
High changes (vs low)	1	1.1	8	5.2	.098
Subsidence/shift	1	1.1	1	0.7	.709
Lucencies	0	0.0	0	0.0	1.000
Radiographic at-risk for humeral loosening	1	1.1	1	0.7	.709

RTSA, reverse total shoulder arthroplasty; *SD*, standard deviation.
Bold font indicates a statistically significant difference.

were also seen in the standard-length stem group, patients in the short stem group had better ASES and WOOS scores at 2 years as well as greater mobility (FF and IR). The improved ROM in the short stem group is likely multifactorial, and may include the increase in lateralization with the short stem group. Many of the patients in the short stem group had a newer baseplate (MGS) that afforded more lateralization, which likely contributed to improved ROM. Furthermore, although the better functional outcomes may be multifactorial as well, the reduced stem length may have contributed to decreased pain, affording these patients better clinical outcome scores. However, these differences are mild and did not reach MCID thresholds.[11] Finally, there was a higher percentage of male patients in the short stem group. Although this did not appear to have any effect on the outcomes, it should be noted that there may be an inherent selection bias to choose a shorter stem in male patients.

Limitations

This study reported the short-term outcomes of the short humeral stem for RTSA and as such cannot comment on the long-term outcomes. These patients will continue to be followed so mid- to long-term outcomes can be obtained and reported. There were several surgeons included in this study who performed the RTSA. Although all surgeons performed the surgery through a deltopectoral approach, stem selection was based on availability (the short stem became available mid-way through the study period) and surgeon preference. There may be differences based on bone quality that were not able to be evaluated in this study. Differences in glenoid components, lateralization, or alignment from advances in preoperative planning may have had an effect on the postoperative ROM. Also, with the recent pandemic, there were many patients who did not return to the office for follow-up X-rays. Although we have clinical outcomes on many patients, the radiographic follow-up was difficult with the current global situation. This may have introduced a selection bias. Finally, this study reported on uncemented humeral components done in primary surgeries. These results may not translate to cemented components or to revision cases.

Conclusion

A short inlay stem leads to comparable radiographic findings and revision-free survival compared with a standard-length stem when placed with a press-fit technique for RTSA. Clinical outcomes are also equivalent or slightly improved with a short stem compared with a standard-length stem.

Disclaimer:

Funding: This study was funded by Arthrex Inc.
Conflicts of Interest: Brandon J. Erickson—AAOS: board or committee member; American Orthopaedic Society for Sports Medicine: board or committee member; American Shoulder and Elbow Surgeons: board or committee member; Arthrex, Inc: paid consultant and research support; DePuy, A Johnson & Johnson Company: research support; Linvatec: research support; PLOS One: editorial or governing board; Smith & Nephew: research support; Stryker: research support. Patrick Denard—Arthrex, Inc: IP royalties, paid consultant, paid presenter or speaker, research support, orthopedics; Today: editorial or governing board; Pacira: paid presenter or speaker; Wolters Kluwer Health - Lippincott Williams & Wilkins: publishing royalties and financial or material support. Justin Griffin—American Shoulder and Elbow Surgeons: board or committee member; Arthrex, Inc: IP royalties, paid consultant, paid presenter or speaker, research support; Arthroscopy Association of North America: board or committee member; Springer: publishing royalties, financial or material support. Evan Lederman—American Shoulder and Elbow Surgeons: board or committee member; Arthrex, Inc: IP royalties, paid consultant, paid presenter or speaker, research support; PTGenie: stock or stock options; Smart Medical Devices Inc: stock or stock options. Reuben Gobezie—Arthrex, Inc: IP royalties, paid consultant, paid presenter or speaker, research support; Research Committee – American Shoulder & Elbow Surgeons, Closed and Open Program Committee – American Shoulder & Elbow Surgeons, Technology Committee – American Shoulder & Elbow Surgeons, Research Committee – OREF, Research Committee – AANA, Shoulder and Elbow Program Committee – AAOS, board or committee member. Brian Werner—AAOS: board or committee member; American Orthopaedic Society for Sports Medicine: board or committee member; American Shoulder and Elbow Surgeons: board or committee member; Arthrex, Inc: paid consultant, paid presenter or speaker, research support; Biomet: research support; Exactech, Inc: research support; Flexion Therapeutics: research support. Patric Raiss—DVSE: board or committee member; SECEC/ ESSSE: board or committee member; Wright Medical Technology, Inc.: paid consultant, paid presenter

or speaker. The other author, his immediate family, and any research foundation with which he is affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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