Subscapularis Tenotomy Versus Lesser Tuberosity Osteotomy for Total Shoulder Arthroplasty: A Systematic Review

Philip K. Louie, MD, David M. Levy, MD, Bernard R. Bach Jr, MD, Gregory P. Nicholson, MD, and Anthony A. Romeo, MD

Abstract

Subscapularis tenotomy (ST) has been the standard method of mobilizing the subscapularis during the approach to a total shoulder arthroplasty (TSA). Recently, lesser tuberosity osteotomy (LTO), which avoids subscapularis complications, has gained in popularity.

We performed a systematic review to elucidate any differences in clinical or radiographic outcomes between ST and LTO. Using PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, we identified clinical and/or radiographic TSA studies with minimum mean 2-year follow-up and level I to IV evidence. Twenty studies (1420 shoulders, 1392 patients) were included in the study.

The ST group had significantly more patients with osteoarthritis ($P = .03$) and fewer patients with posttraumatic arthritis ($P = .04$). At final follow-up, mean (SD) forward elevation improvements were significantly ($P < .01$) larger for the ST group, +50.9° (17.5°) than for the LTO group, +31.3° (0.9°). Complication rates were almost identical, but the ST group showed a trend ($P = .31$) toward fewer revisions (10.0% vs 16.2%). There were no differences in Constant scores, pain scores, or radiolucencies. Both approaches (ST, LTO) produced excellent outcomes.

ST may result in wider range of motion and fewer revisions, but more studies are needed to further evaluate these results.

During total shoulder arthroplasty (TSA) exposure, the subscapularis muscle must be mobilized; its repair is crucial to the stability of the arthroplasty. The subscapularis is the largest rotator cuff muscle and has a contractile force equal to that of the other 3 muscles combined.[1,2] Traditionally it is mobilized with a tenotomy just medial to the tendon's insertion onto the lesser tuberosity. Over the past 15 years, however, numerous authors have reported dysfunction after subscapularis tenotomy (ST). In 2003, Miller and colleagues[3] reported that, at 2-year follow-up, almost 70% of patients had abnormal belly-press and liftoff tests, surrogate markers of subscapularis function. Other authors have found increased rates of anterior instability after subscapularis rupture.[4,5]

In 2005, Gerber and colleagues[6] introduced a technique for circumventing surgical division of the subscapularis. They described a lesser tuberosity osteotomy (LTO), in which the subscapularis tendon is detached with a bone fragment 5 mm to 10 mm in thickness and 3 cm to 4 cm in length. This approach was based on the premise that bone-to-bone healing is more reliable than tendon-to-tendon healing. Initial studies reported successful

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Take-Home Points

- According to the orthopedic literature, ST and LTO for a TSA produce excellent clinical outcomes, and technique selection should be based on surgeon discretion and expertise.
- Compared with the LTO approach, the ST approach produced significantly more forward elevation improvement and trended toward more external rotation and abduction and fewer revisions.
- ST and LTO approaches for a TSA result in similar Constant scores, pain scores, radiographic outcomes, and complication rates.

osteotomy healing, improved clinical outcome scores, and fewer abnormalities with belly-press and liftoff tests.[2,6] More recent literature, however, has questioned the necessity of LTO.[2,4,7-9]

We performed a systematic review to evaluate the literature, describe ST and LTO, and summarize the radiographic and clinical outcomes of both techniques. We hypothesized there would be no significant clinical differences between these approaches.

Methods

Search Strategy and Study Selection

Using PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, we systematically reviewed the literature.[10] Searches were completed in September 2014 using the PubMed Medline database and the Cochrane Central Register of Clinical Trials. Two reviewers (Dr. Louie, Dr. Levy) independently performed the search and assessed eligibility of all relevant studies based on predetermined inclusion criteria. Disagreements between reviewers were resolved by discussion. Key word selection was designed to capture all English-language studies with clinical and/or radiographic outcomes and level I to IV evidence. We used an electronic search algorithm with key words and a series of NOT phrases to match certain exclusion criteria:

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Study exclusion criteria consisted of cadaveric, biomechanical, histologic, and kinematic results as well as analyses of nonoperative management, hemiarthroplasty, or reverse TSA. Studies were excluded if they did not report clinical and/or radiographic data. Minimum mean follow-up was 2 years. To discount the effect of other TSA technical innovations, we evaluated the same period for the 2 surgical approaches. The first study with clinical outcomes after LTO was published in early 2005,[6] so all studies published before 2005 were excluded.

We reviewed all references within the studies included by the initial search algorithm: randomized control trials, retrospective and prospective cohort designs, case series, and treatment studies. Technical notes, review papers, letters to the editor, and level V evidence reviews were excluded. To avoid counting patients twice, we compared each study's authors and data collection period with those of the other studies. If there was overlap in authorship, period, and place, only the study with the longer follow-up or more comprehensive data was included. All trials comparing ST and LTO were included. If the authors of a TSA study did not describe the approach used, that study was excluded from our review.

Data Extraction

We collected details of study design, sample size, and patient demographics (sex, age, hand dominance, primary diagnosis). We also abstracted surgical factors about the glenoid component (cemented vs uncemented; pegged vs keeled; all-polyethylene vs metal-backed) and the humeral component (cemented vs press-fit; stemmed vs stemless). Clinical outcomes included pain scores, functional scores, number of revisions, range of motion (ROM), and subscapularis-specific tests (eg, belly-press, liftoff). As pain scales varied between studies, all values were converted to a 10-point scoring scale (0 = no pain; 10 = maximum pain) for comparisons. Numerous functional outcome scores were reported, but the Constant score was the only one consistently used across studies, making it a good choice for comparisons. One study used Penn Shoulder Scores (PSSs) and directly compared ST and LTO groups, so its data were included. In addition, radiographic data were compiled: radiolucencies around the humeral stem and glenoid component, humeral head subluxation/migration, and osteotomy healing. The only consistent radiographic parameter available for comparisons between groups was the presence of radiolucencies.

The Modified Coleman Methodology Score (MCMS), described by Cowan and colleagues,[11] was used to evaluate the methodologic quality of each study. The MCMS is a 15-item instrument that has been used to assess both randomized and nonrandomized trials.[12,13] It has a scaled score ranging from 0 to 100 (85-100, excellent; 70-84, good; 55-69, fair; <55, poor). Study quality was not factored into the data synthesis analysis.

Statistical Analysis

Data are reported as weighted means and standard deviations. A mean was calculated for each study reporting on a respective data point and was then weighed according to the study sample size. The result was that the nonweighted means from studies with smaller samples did not carry as much weight as those from studies with larger samples. Student *t* tests and 2-way analysis of variance were used to compare the ST and LTO groups and assess differences over time (SPSS Version 18; IBM). An α of 0.05 was set as statistically significant.

Results

Twenty studies (1420 shoulders, 1392 patients) were included in the final dataset (**Figure**).[2,6,8,14-30] **Table 1** lists the demographic characteristics of included patients. Of the 20 studies, 12 reported level IV evidence, 6 reported level III, 1 reported level II, and 1 reported level I. Mean (SD) MCMS was 51.9 (11.2) for ST studies and 46.3 (8.1) for LTO studies.

The youngest patients in the ST and LTO groups were 22 years and 19 years of age, respectively. The oldest patient in each group was 92 years of age. On average, the ST study populations (mean

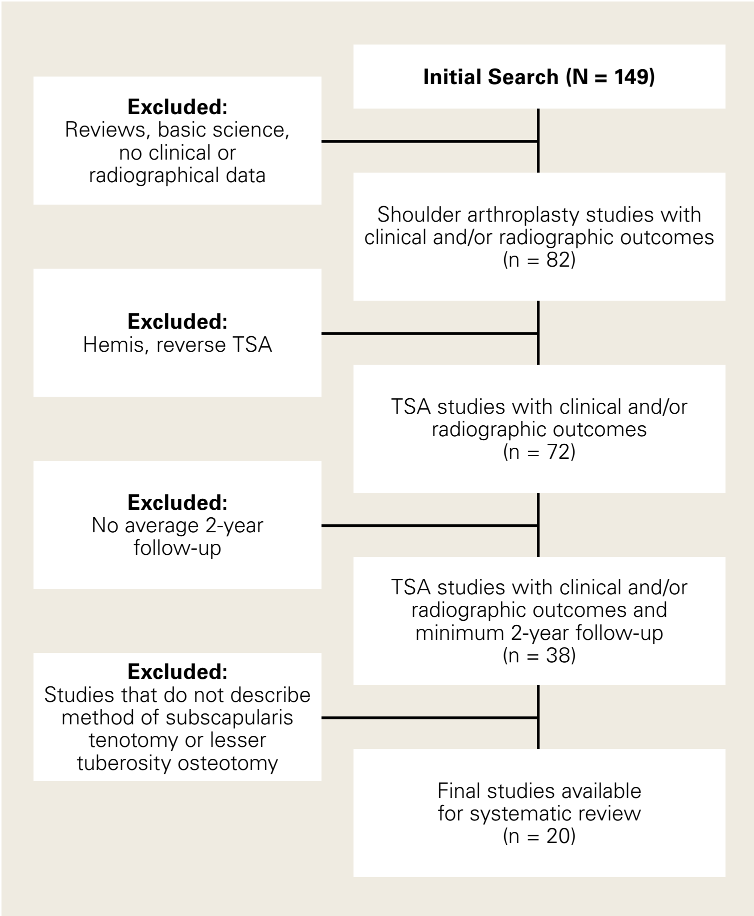

Figure. **PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow chart of search strategy.**
Abbreviation: TSA, total shoulder arthroplasty.

age, 66.6 years; SD, 2.0 years) were older (*P* = .04) than the LTO populations (mean age, 62.1 years; SD, 4.2 years). The ST group had a higher percentage of patients with osteoarthritis (*P* = .03) and fewer patients with posttraumatic arthritis (*P* = .04). There were no significant differences in sex, shoulder side, or shoulder dominance between the 2 groups.

Table 2 lists the details regarding the surgical components. For glenoid components, the ST and LTO groups' fixation types and material used were not significantly different. There was a significant (*P* < .01) difference in use of pegged (vs keeled) glenoid components (all LTO components were pegged). There was also a significant (*P* = .04) difference in use of cement for humeral components (the ST group had a larger percentage of cemented humeral components). There were no other significant differences in components between the groups. When subgroup analysis was applied to keeled glenoid components and

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Table 1. **Demographics and Clinical Diagnoses for Final Cohort of Included Patients**

Parameter	Subscapularis Tenotomy	Lesser Tuberosity Osteotomy	*P*
Sample size[2-5,8,11,15-17,20-23,27-33]			
Patients			
Total	758	634	
Mean	40	58	
Range	14-124	10-183	
Shoulders			
Total	788	642	
Mean	41	58	
Range	15-140	10-183	
Sex[2-5,8,11,16,20,22,23,27-33]			.35
Male	341 (45.9%)	245 (38.7%)	
Female	402 (54.1%)	389 (61.3%)	
Mean (SD) age, y[2-5,8,11,15-17,20-23,27-33]	66.6 (2.0)	62.1 (4.2)	.04[a]
Shoulder side[3,8,15,21,28,29,32,33]			.77
Right	205 (55.4%)	143 (69.7%)	
Left	165 (44.6%)	99 (30.3%)	
Shoulder dominance[2,4,8,15,21,22,28]			.94
Dominant	172 (56.9%)	28 (56.0%)	
Nondominant	130 (43.1%)	22 (44.0%)	
Primary diagnosis[2-5,8,11,15-17,20-23,27-31,33]			
Osteoarthritis	688 (87.8%)	291 (64.0%)	.03[a]
Rheumatoid arthritis	54 (6.9%)	99 (21.8%)	.09
Posttraumatic arthritis	13 (1.6%)	57 (12.6%)	.04[a]
Other	29 (3.7%)	17 (1.6%)	.24

[a]Statistically significant.

Table 2. **Surgical Details for Final Cohort of Included Patients**

	Shoulders, n (%)		
Characteristics	**Subscapularis Tenotomy**	**Lesser Tuberosity Osteotomy**	***P***
Glenoid			
Fixation[2,3,5,8,11,16,17,20-23,27-33]			.21
Cemented	490 (75.6%)	354 (55.1%)	
Uncemented	158 (34.4%)	288 (44.9%)	
Design[2,3,8,11,17,20,22,23,29]			<.01[a]
Pegged	248 (59.3%)	87 (100.0%)	
Keeled	170 (40.7%)	0 (0.0%)	
Material[2,3,5,8,11,16,17,20-23,27,28,30-33]			.94
All-polyethylene	379 (62.9%)	354 (55.6%)	
Metal-backed	224 (37.1%)	282 (44.4%)	
Humeral			
Fixation[2-5,8,11,15-17,20-23,27-33]			.04[a]
Cemented	217 (32.0%)	9 (1.5%)	
Press-fit	461 (68.0%)	590 (98.5%)	
Design buckle[2-5,8,11,15-17,20-23,27-33]			.41
Stemmed	739 (97.8%)	638 (100.0%)	
Stemless	17 (2.0%)	0 (0.0%)	

[a]Statistically significant.

Table 3. **Preoperative and Postoperative Clinical Outcome Data and Postoperative Radiologic Outcomes for All Patients Included in Final Analysis**

	Weighted Mean (SD)		
Follow-Up	**Subscapularis Tenotomy**	**Lesser Tuberosity Osteotomy**	***P***
Physical examination			
Months	51.6 (34.7)	50.2 (31.1)	.85
Normal belly-press test, %[4,11,15,27]	94.7 (14.1)	87.9 (10.6)	.75
Forward elevation[2-5,8,16,17,20-23,28,29]			<.01[a]
N	617	55	
Preoperative, °	80.3 (18.1)	78.1 (5.4)	
Postoperative, °	132.7 (9.5)	122.5 (19.9)	
Δ	+50.9 (17.5)	+31.3 (0.9)	
External rotation[2-5,11,15-17,20-23,28,29,31,33]			.21
N	730	92	
Preoperative, °	19.1 (6.3)	12.8 (5.0)	
Postoperative, °	49.8 (9.8)	43.7 (14.3)	
Δ	+30.0 (7.6)	+26.4 (5.2)	.26
Abduction[2,5,8,15-17,21,28,29,33]			
N	385	55	
Preoperative, °	51.4 (29.5)	63.0 (6.1)	
Postoperative, °	99.7 (31.8)	107.9 (21.2)	
Δ	+43.7 (25.6)	+32.8 (17.8)	
Clinical survey			
Months	45.2 (30.9)	47.8 (26.6)	.87
Constant score[2,5,8,11,17,22,28]			.37
N	73	55	
Preoperative	24.4 (3.9)	25.3 (4.5)	
Postoperative	76.6 (9.3)	63.0 (18.0)	
Δ	+40.7 (10.2)	+28.0 (10.3)	.74
Pain score[3,8,11,17,20,22,23,27]			
N	209	55	
Preoperative	7.0 (2.0)	7.3 (0.1)	
Postoperative	2.0 (0.7)	2.1 (1.0)	
Δ	−4.9 (1.9)	−5.1 (0.9)	
Radiology			
Months	50.1 (32.0)	43.2 (26.0)	.60
N	457	282	—
Glenoid radiolucencies, %[3,5,15,21-23,28-30,33]	42.3 (26.4)	40.7 (37.7)	.76

[a]Statistically significant.

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uncemented humeral components in the ST study populations, there were no significant changes in the radiographic or clinical trends.

Table 3 lists the clinical and radiographic outcomes most consistently reported in the literature. Physical examination data were reported in 18 ST populations[8,14-16,21-30] and 11 LTO populations.[2,6,14-20] Mean (SD) forward elevation improvements were significantly ($P < .01$) larger for the ST group, +50.9° (17.5°), than for the LTO group, +31.3° (0.9°). There were no significant differences in preoperative/postoperative shoulder external rotation or abduction. In a common method of testing internal rotation, the patient is asked to internally rotate the surgical arm as high as possible behind the back. Internal rotation improved from L4–S1 (before surgery) to T5–T12 (after surgery) in the ST group[8,16,24,26,28,29] and from S1 to T7–T12 in the LTO group.[16,31] There were isolated improvements in other subscapularis-specific tests, such as belly-press resistance (lb),[14] belly-press force (N),[15] bear hug resistance (lb),[14,23] liftoff,[2,8,16] and ability to tuck in one's shirt,[2,16,23] but data were insufficient for comparisons between the 2 groups.

Constant scores were reported in 4 ST studies[14,22,24,27] and 3 LTO studies[14,17,18] (Table 3). There was no significant difference ($P = .37$) in post-TSA Constant score improvement between the 2 groups. In the one study that performed direct comparisons, PSS improved on average from 29 to 81 in the ST group and from 29 to 92 in the LTO group.[15] Several ST studies reported improved scores on various indices: WOOS (Western Ontario Osteoarthritis of the Shoulder), ASES (American Shoulder and Elbow Surgeons), SST (Simple Shoulder Test), DASH (Disabilities of the Arm, Shoulder, and Hand), SF-12 (Short Form 12-Item Health Survey), MACTAR (McMaster Toronto Arthritis Patient Preference Disability Questionnaire), and Neer shoulder impingement test.[8,14,15,21,23-25,27-30] However, these outcomes were not reported in LTO cohorts for comparison. Similarly, 2 LTO cohorts reported improvements in SSV (subjective shoulder value) scores, but this measure was not used in the ST cohorts.[6,17] Five ST studies recorded patients' subjective satisfaction: 58% of patients indicated an excellent outcome, 35% a satisfactory outcome, and 7% a less than satisfactory outcome.[21,23,25,26,29] Only 1 LTO study reported patient satisfaction: 69% excellent, 31% satisfactory, 0% dissatisfied.[17]

Complications were reported in 16 ST studies[8,15,21-30] and 6 LTO studies.[15,17-19] There were 117 complications (17.8%) and 58 revisions (10.0%) in the ST group and 52 complications (17.2%) and 49 revisions (16.2%) in the LTO group. In the ST group, aseptic loosening (6.2%) was the most common complication, followed by subscapularis tear or attenuation (5.2%), dislocation (2.1%), and deep infection (0.5%). In the LTO group, aseptic loosening was again the most common (9.0%), followed by dislocation (4.0%), subscapularis tear or attenuation (2.2%), and deep infection (0.7%). There were no significant differences in the incidence of individual complications between groups. The difference in revision rates was not statistically significant (P = .31).

Radiolucency data were reported in 12 ST studies[19,21-26,28,30] and 2 LTO studies.[17,18] There were no discussions of humeral component radiolucencies in the LTO studies. At final follow-up, radiolucencies of the glenoid component were detected in 42.3% of patients in the ST group and 40.7% of patients in the LTO group (P = .76).

Discussion

Our goal in this systematic review was to analyze outcomes associated with ST and LTO in a heterogenous TSA population. We hypothesized TSA with ST or LTO would produce similar clinical and radiographic outcomes. There were no significant differences in Constant scores, pain scores, radiolucencies, or complications between the 2 groups. The ST group showed trends toward wider ROM improvements and fewer revisions, but only the change in forward elevation was significant. The components used in the 2 groups were similar with the exception of a lack of keeled glenoids and cemented humeral stems in the LTO group; data stratification controlling for these differences revealed no change in outcomes.

The optimal method of subscapularis mobilization for TSA remains a source of debate. Jackson and colleagues[23] found significant improvements in Neer and DASH scores after ST. However, 7 of 15 patients ruptured the subscapularis after 6 months and had significantly lower DASH scores. In 2005, Gerber and colleagues[6] first described the LTO technique as an alternative to ST. After a mean of 39 months, 89% of their patients had a negative belly-press test, and 75% had a normal liftoff test. Radiographic evaluation revealed that the osteotomized fragment had healed in an anatomical position in all shoulders. In a large case series, Small and colleagues[20] used radiographs and computed tomography to further investigate LTO healing rates and found that 89% of patients had bony union by 6 months and that smoking was a significant risk factor for nonunion.

Biomechanical studies comparing ST and LTO approaches have shown mixed results. Ponce and colleagues[2] found decreased cyclic displacement and increased maximum load to failure with LTO, but Giuseffi and colleagues[32] showed less cyclic displacement with ST and no difference in load to failure. Others authors have found no significant differences in stiffness or maximum load to failure.[33] Van den Berghe and colleagues[7] reported a higher failure rate in bone-to-bone repairs compared with tendon-to-tendon constructs. Moreover, they found that suture cut-out through bone tunnels is the primary mode of LTO failure, so many LTO surgeons now pass sutures around the humeral stem instead.

Three TSA studies directly compared ST and LTO approaches. Buckley and colleagues[14] analyzed 60 TSAs and found no significant differences in WOOS, DASH, or Constant scores between groups. The authors described an ST subgroup with subscapularis attenuation on ultrasound but did not report the group as having any inferior functional outcome. Scalise and colleagues[15] showed improved strength and PSSs in both groups after 2 years. However, the LTO group had a lower rate of subscapularis tears and significantly higher PSSs. Finally, Jandhyala and colleagues[16] reported more favorable outcomes with LTO, which trended toward wider ROM and significantly higher belly-press test grades. Lapner and colleagues[34] conducted a randomized, controlled trial (often referenced) and found no significant differences between the 2 groups in terms of strength or functional outcome at 2-year follow-up. Their study, however, included hemiarthroplasties and did not substratify the TSA population, so we did not include it in our review.

Our systematic review found significantly more forward elevation improvement for the ST group than the LTO group, which may suggest improved ROM with a soft-tissue approach than a bony approach. At the same time, the ST group trended toward better passive external rotation relative to the LTO group. This trend indicates fewer constraints to external rotation in the ST group, possibly attributable to a more attenuated subscapularis after tenotomy. Subscapularis tear or attenuation was more commonly reported in the ST group than in the LTO group, though not significantly so. This may indicate that more ST studies than LTO studies specially emphasized postoperative subscapularis function, but these data also highlight some authors' concerns regarding subscapularis dysfunction after tenotomy.[6,15,16]

The study populations' complication rates were similar, just over 17%. The LTO group trended toward a higher revision rate, but it was not statistically significant. The LTO group also had significantly fewer patients with osteoarthritis and more patients with posttraumatic arthritis, so this group may have had more complex patients predisposed to a higher likelihood of revision surgery. Revisions were most commonly performed for aseptic loosening; theoretically, if osteotomies heal less effectively than tenotomies, the LTO approach could produce component instability and aseptic loosening. However, no prior studies or other clinical findings from this review suggest LTO predisposes to aseptic loosening. Overall, the uneven revision rates represent a clinical concern that should be monitored as larger samples of patients undergo ST and LTO procedures.

Glenoid radiolucencies were the only radiographic parameter consistently reported in the included studies. Twelve ST studies had radiolucency data—compared with only 2 LTO studies. Thus, our ability to compare radiographic outcomes was limited. Our data revealed similar rates of glenoid radiolucencies between the 2 approaches. The clinical relevance of radiolucencies is questioned by some authors, and, indeed, Razmjou and colleagues[25] found no correlation of radiolucencies with patient satisfaction. Nevertheless, early presence of radiolucencies may raise concerns about progressive loss of fixation,[35,36] so this should be monitored.

Limitations of this systematic review reflect the studies analyzed. We minimized selection bias by including level I to IV evidence, but most studies were level IV, and only 1 was level I. As such, there was a relative paucity of consistent clinical and radiographic data. For instance, although many ST studies reported patient satisfaction as an outcomes measure, only 1 LTO study commented on it. Perhaps the relative novelty of the LTO approach has prompted some authors to focus more on technical details and less on reporting a variety of outcome measures. As mentioned earlier, the significance of radiolucency data is controversial, and determination of their presence or absence depends on the observer. A radiolucency found in one study may not qualify as one in a study that uses different criteria. However, lucency data were the most frequently and reliably reported radiographic parameter, so we deemed it the most appropriate method for comparing radiographic outcomes. Finally, the baseline differences in diagnosis between the ST and LTO groups complicated comparisons. We stratified the groups by component design because use of keeled or pegged implants or humeral cemented or press-fit stems was usually a uniform feature of each study—enabling removal of certain studies for data stratification. However, we were unable to stratify by original diagnosis because these groups were not stratified within the individual studies.

Conclusion

Our systematic review found similar Constant scores, pain scores, radiographic outcomes, and complication rates for the ST and LTO approaches. Compared with the LTO approach, the ST approach produced significantly more forward elevation improvement and trended toward more external rotation and abduction and fewer revisions. Although not definitive, these data suggest the ST approach may provide more stability over the long term, but additional comprehensive studies are needed to increase the sample size and the power of the trends elucidated in this review. According to the orthopedic literature, both techniques produce excellent clinical outcomes, and technique selection should be based on surgeon discretion and expertise.

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This paper will be judged for the Resident Writer's Award.