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Subscapularis management in stemless total shoulder arthroplasty: tenotomy versus peel versus lesser tuberosity osteotomy

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Background: It is unknown whether subscapularis management technique has an influence on the outcomes and complications of stemless total shoulder arthroplasty. The purpose of this study, therefore, was to compare outcomes and complications between subscapularis tenotomy, peel, and lesser tuberosity osteotomy used during stemless shoulder arthroplasty.
Methods: We reviewed 188 stemless anatomic total shoulder arthroplasties and compared clinical and functional outcomes between those performed through a subscapularis tenotomy (n = 68), subscapularis peel (n = 65), or lesser tuberosity osteotomy (n = 55). Patients were followed up clinically and radiographically at 6 months, 1 year, and 2 years postoperatively.
Results: At 2 years postoperatively, no statistically significant differences in visual analog scale pain scores, American Shoulder and Elbow Surgeons scores, or patient-reported instability ($P \geq .19$) were found between groups. Active external rotation was greater in the peel group ($P = .006$) than in the tenotomy group but was not different compared with the lesser tuberosity osteotomy group ($P = .07$). No statistically significant difference in clinical subscapularis failures was noted between groups ($P = .11$); however, 2 patients in the peel group sustained a subscapularis failure requiring reoperation.
Discussion: The results of this multicenter comparative analysis show that all 3 subscapularis management techniques are effective and safe in the short term when used with stemless anatomic total shoulder arthroplasty.

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In the past decade, stemless anatomic total shoulder arthroplasty (TSA) has been gaining popularity worldwide. In recent years, several early-term and midterm outcome studies have shown satisfactory results with various stemless humeral prostheses.[2,5,6,7,8,19] Even long-term results are now available that have been shown to be comparable to the results of stemmed TSA.[2,7,19] Although there are several reported advantages of stemless implants, there are also disadvantages, such as questionable fixation in poor-quality bone and concern with lesser tuberosity osteotomy (LTO) for exposure.

Various techniques for management of the subscapularis tendon during exposure for a shoulder arthroplasty exist. The most common include subscapularis tenotomy, subscapularis peel, and LTO. The tenotomy involves an intratendinous division of the subscapularis tendon, whereas the peel completely detaches the subscapularis insertion from the lesser tuberosity. The LTO involves maintenance of the subscapularis tendon attachment on the tuberosity.[17] A recent systematic review showed no significant difference between subscapularis management techniques after stemmed shoulder arthroplasty.[4] In addition, in a level I randomized prospective study, Lapner et al[11] showed no superiority of LTO over the subscapularis peel approach in stemmed anatomic arthroplasty at 2 years' follow-up. Recently, Levine at al[12] also conducted a randomized prospective study comparing tenotomy with LTO in stemmed TSA and found no statistically significant differences in objective or subjective clinical outcomes at 1 year of follow-up.

Most of the published literature on stemless TSA has reported the use of a subscapularis tenotomy,[2,6,7,19] whereas 1 prospective multicenter study reported that the subscapularis was managed based on surgeon preference.[5] The latter did not report the distribution of subscapularis tenotomy, subscapularis peel, or LTO procedures. The available literature does include 2 cases of subscapularis tendon failure after a stemless TSA.[5,6] One failure occurred after an arthroplasty performed with the tenotomy approach,[6] whereas the authors of the study including the second failure did not report which approach resulted in the failure.[5] In addition, anecdotally, it has been stated that LTOs should be conducted with caution when using stemless implants because of the risk of compromising implant fixation in the metaphyseal bone and periprosthetic fracture. The purpose of this study, therefore, was to compare clinical outcomes and complications between subscapularis tenotomy, subscapularis peel, and LTO approaches used during stemless anatomic TSA at a minimum of 2 years' follow-up.

Methods

We prospectively followed and retrospectively compared 188 stemless TSAs at a minimum follow-up of 2 years or until reoperation. These arthroplasties were performed as part of a US Food and Drug Administration Investigational Device Exemption study in North America and a European post-market clinical follow-up study.[10] The inclusion criteria for the patients enrolled in this study were age of 18 years or older, skeletal maturity, patients with primary osteoarthritis in whom conservative treatment failed and shoulder arthroplasty was indicated, willingness to participate in the study follow-up period, and ability to provide informed consent. The exclusion criteria included the following: patients who were considered vulnerable adults (prisoners, current abusers of illicit drugs or alcohol, or patients with active psychiatric illness preventing the ability to provide informed consent), unwillingness to participate in the study follow-up, inability to comply with the postoperative protocol, pregnancy, Charcot arthropathy, irreparable rotator cuff tear, evidence of infection, post-traumatic etiology, metaphyseal osseous defect, and soft or inadequate humeral bone. Five deaths occurred, 4 patients withdrew from the study, 3 patients were lost to follow-up, and 6 patients did not present for their 2-year follow-up visit, leaving a total of 170 shoulders available for analysis. All surgical procedures were performed by 24 experienced shoulder arthroplasty surgeons in the United States, Canada, and Europe using the same implant (Sidus; Zimmer-Biomet, Warsaw, IN, USA).

Patients were followed up at standard intervals and assessed at 6 months, 1 year, and 2 years postoperatively. Outcome measures included the visual analog scale (VAS) pain score, active range of motion (ROM), American Shoulder and Elbow Surgeons (ASES) score, and Shoulder Instability Score. The Shoulder Instability Score is a patient assessment that uses a VAS from 0 (very stable) to 10 (very unstable).[15] Complications and reoperations were recorded as well. Patient demographic characteristics and distributions across groups are reported in Table I. Anteroposterior and axillary radiographs were reviewed by 2 independent musculoskeletal radiologists (Medical Metrics, Houston, TX, USA). Radiographs were assessed for radiolucencies, humeral implant subsidence or migration, LTO status, and joint subluxation.

A deltopectoral approach was used uniformly. The subscapularis was managed based on surgeon preference, with a subscapularis tenotomy performed in 63 shoulders, a subscapularis peel performed in 61, and an LTO performed in 46. In addition, the specific technique used to perform the tenotomy, peel, or osteotomy and achieve repair was up to the participating surgeons. Once exposed and dislocated, humeral osteophytes were

Table I Patient demographic characteristics

	Subscapularis tenotomy (n = 68)	Subscapularis peel (n = 65)	LTO (n = 55)	*P* value
Mean age (range), yr	64 (44-80)	60 (33-81)	62 (44-76)	.04*
% Female sex	54	42	51	.31
Mean BMI (range), kg/m^2	29 (20-53)	30 (18-48)	30 (21-50)	.43

LTO, lesser tuberosity osteotomy; *BMI*, body mass index.
* Statistically significant.

removed, and a humeral neck osteotomy was performed. The metaphyseal bone quality was subjectively assessed to determine suitability to accept a stemless humeral prosthesis. The glenoid was then prepared in a standard fashion, and a polyethylene implant was cemented into place. The humeral head position and diameter, as well as the humeral anchor size, were determined and selected according to the implant manufacturer's technique guide. The humeral anchor was then impacted, and a trial head was positioned. The glenohumeral joint was reduced and assessed for stability. The real stemless implant and humeral head were then implanted. The subscapularis was repaired in all cases based on surgeon preference. The wound was closed. All patients followed a standard postoperative rehabilitation protocol that involved initiation of early passive ROM on postoperative day 1 or 2 and use of a sling for a total of 6 weeks. At week 3 postoperatively, patients were encouraged to conduct gentle active ROM for activities of daily living. At 6 weeks, use of the sling was discontinued and full active ROM was encouraged. At 12 weeks, rotator cuff and deltoid strengthening exercises were initiated. This rehabilitation protocol was the same regardless of the technique of subscapularis management.

Statistical methods

Continuous data are reported as means and ranges. Group comparisons for pain, ROM, and functional scores were performed using analysis of variance. Pair-wise comparisons were performed using *t* tests. Categorical data were compared using χ^2 analysis. Statistical significance was considered at $P < .05$.

Results

Outcomes

The mean VAS pain score improved uniformly in all 3 groups. No statistically significant difference ($P = .20$) in pain score was noted between subscapularis groups at any time point (Table II). At 6 months and 1 year of follow-up, the LTO group reported a greater sense of stability compared with the peel group ($P = .005$ and $P = .016$, respectively). However, at 2 years' follow-up, no statistically significant difference in the Shoulder Instability Score ($P = .23$) was noted between the tenotomy (0.3), peel (0.4), and LTO (0.1) groups.

Active ROM improved uniformly in all 3 groups regarding forward elevation, external rotation with the arm at the side, and external rotation at 90° of abduction (Table II). At 6 months and at 1 year, mean external rotation in both arm positions was greatest in the subscapularis peel group, whereas forward elevation was greatest in the tenotomy group. At 2 years, the peel group had significantly better active external rotation (55°) than the tenotomy group (mean, 45°; $P = .006$) but was no different than the LTO group (mean, 48°; $P = .07$). Pair-wise comparisons are reported in Table III.

ASES scores improved uniformly in all 3 groups (Table II). No differences related to ASES scores were found between the groups at any of the follow-up time points. Pair-wise comparisons at 2 years' follow-up also did not reveal any statistically significant differences (Table III).

Radiographically, at 2 years' follow-up, no humeral components were found to have migrated or subsided. In addition, no radiographic joint subluxations or dislocations occurred. No LTOs were found to have displaced on axillary radiographs. There was 1 case of humeral radiographic lucency greater than 4 mm at 2 years' follow-up located at the medial calcar. This occurred in the peel group and was non-progressive and not associated with any implant migration or loosening.

Operative data

No statistically significance differences were found between groups with respect to the average operating room time. The mean operating room time was 116 minutes (range, 70-195 minutes) for the tenotomy group, 105 minutes (range, 61-171 minutes) for the peel group, and 99 minutes (range, 45-161 minutes) for the LTO group ($P = .29$).

Complications and reoperations

No statistically significant differences were noted between groups with respect to complications and reoperations ($P > .05$). There were 2 subscapularis failures, both of which occurred in the subscapularis peel group and underwent revision at 6 months after the index arthroplasty. In 1 instance, an acute subscapularis rupture was noted 6 months after the index procedure, and the patient underwent reoperation to repair the avulsed subscapularis tendon.

Table II Clinical and functional outcomes

	Subscapularis tenotomy (n = 68)	Subscapularis peel (n = 65)	LTO (n = 55)	*P* value
VAS pain score				
6 mo	0.8 (0-9.8)	1.5 (0-8.5)	1.2 (0-6.2)	.09
1 yr	0.5 (0-6.0)	0.8 (0-8.6)	0.9 (0-6.9)	.33
2 yr	0.5 (0-7.6)	0.7 (0-7.8)	1.0 (0-7.0)	.20
ER at 90° of abduction, °				
6 mo	62 (0-100)	60 (0-98)	50 (0-90)	.04*
1 yr	69 (0-100)	67 (0-100)	55 (10-90)	.003*
2 yr	66 (0-108)	66 (10-105)	61 (20-90)	.50
ER at side, °				
6 mo	42 (0-75)	47 (10-90)	37 (0-70)	.006*
1 yr	45 (10-90)	54 (15-90)	44 (0-70)	.003*
2 yr	45 (0-90)	55 (20-88)	48 (0-80)	.02*
Forward elevation, °				
6 mo	142 (70-170)	130 (40-180)	130 (20-170)	.02*
1 yr	153 (80-180)	137 (75-150)	141 (60-180)	.002*
2 yr	152 (45-180)	142 (85-180)	147 (30-180)	.13
ASES score				
6 mo	85 (28-100)	78 (14-100)	82 (20-100)	.09
1 yr	91 (55-100)	87 (20-100)	88 (20-100)	.50
2 yr	91 (42-100)	90 (38-100)	89 (16-100)	.76

LTO, lesser tuberosity osteotomy; *VAS*, visual analog scale; *ER*, external rotation; *ASES*, American Shoulder and Elbow Surgeons.
Data are presented as mean (range).
* Statistically significant.

Table III Pair-wise comparisons for clinical and functional outcomes at 2 years' follow-up

	P value		
	Tenotomy vs. peel	Peel vs. LTO	Tenotomy vs. LTO
VAS pain score	.43	.31	.07
ER at 90° of abduction	.99	.30	.30
ER at side	.006* (peel)	.07	.44
Forward elevation	.04* (tenotomy)	.34	.34
ASES score	.66	.76	.47
Shoulder Instability Score	.48	.09	.27

LTO, lesser tuberosity osteotomy; *VAS*, visual analog scale; *ER*, external rotation; *ASES*, American Shoulder and Elbow Surgeons.
* Statistically significant.

In the second case, the patient underwent revision at an outside facility, where the revision operative report stated that the glenoid component was loose, the humeral head was disengaged from the anchor, and the subscapularis peel was disrupted. In the LTO group, there were no reported nonunions.

Discussion

Stemless shoulder arthroplasty is becoming increasingly more prevalent in North America as more systems become available and as surgeon comfort with stemless implants increases. To date, little literature exists on the impact of the subscapularis approach technique on outcomes after stemless TSA. Overall, comparing tenotomy, peel, and LTO, our study found no significant differences in outcome scores, pain, or instability between groups. Anecdotally, caution has been recommended in the use of the LTO with stemless humeral implants because of the theoretical risk of intraoperative fracture or component migration. Our results, however, in the stemless LTO group showed no cases of intraoperative fracture, loss of fixation, or radiographic component subsidence or loosening at 2 years' follow-up. As such, the results of this study indicated that all 3 subscapularis approach techniques can be used with stemless humeral components with generally equivalent outcomes. At final follow-up, the only statistically significant (P = .006) finding between groups was a mean 10° greater active external rotation in the peel group (55°) compared with the tenotomy group (45°). Nonetheless, on the basis of recent literature, the improvements in external rotation with all 3 approaches exceeded the minimally clinically important difference for external rotation in the setting of shoulder arthroplasty.[18]

The postoperative ASES scores for stemmed shoulder prostheses have been reported for each of the 3 subscapularis management techniques. A recent systematic review pooled these results, showing a mean weighted ASES score of 80.8 for tenotomy, 79.1 for peel, and 73.0 for LTO.[4] In our study, the mean postoperative ASES scores at 2 years postoperatively were slightly higher, at 91, 90, and 89, respectively. Several factors may contribute to the slightly higher functional scores in this stemless cohort. First, this may be representative of differences in outcomes of stemless compared with stemmed prostheses; however, this postulate is outside the scope of our study. Second, the pooled data in the systematic review came from several studies with various follow-up time points ranging from 12 to 67 months, whereas our study reported final outcomes at 2 years in all cases.[1,11,13,14] Third, the average age at surgery in our group is generally younger than that in the cited systematic review studies. For instance, in the study by Liem et al,[13] the average age was 71 years, whereas our average age was 62 years. This younger age could be a subconscious surgeon bias related to the selection of patients appropriate for stemless implants or a function of a trend toward performing shoulder arthroplasty in younger patients over time.

Few comparative studies regarding subscapularis management techniques exist. Lapner et al[11] performed a level I randomized controlled trial comparing the subscapularis peel with an LTO in stemmed TSA. Their outcomes included strength and validated functional scores but did not assess ROM. At final follow-up, Lapner et al reported no statistically significant differences in their primary outcome of subscapularis strength or any of the secondary outcomes (ASES and Western Ontario Osteoarthritis of the Shoulder Index scores) between the peel and LTO groups. Buckley et al,[3] in a retrospective comparative cohort study, assessed the outcomes of the subscapularis peel and LTO as well and showed a statistically significant increase in external rotation in the subscapularis peel group. Scalise et al[16] also performed a retrospective comparative cohort study and similarly showed a trend toward greater external rotation in the peel group. The findings in our study also show a trend (P = .07) toward greater external rotation with the arm at the side in the peel group compared with the LTO group, as well as a significant difference (P = .006) compared with the tenotomy group. The increase in external rotation in the peel groups may be due to medialization of the subscapularis insertion during repair or, conversely, may be due to greater tightening of the anterior tissues during LTO or tenotomy repairs. Given that there are several studies that have reported increased external rotation with a subscapularis peel, this finding is likely true; however, it is not possible to determine at this time whether this will have a positive or negative effect on long-term outcomes.

Studies comparing subscapularis management by multiple surgeons may be challenging as technical variability within each of the 3 methods can confound findings. However, the use of data from multiple surgeons (25) from multiple countries (8) in this study is a strength as the findings may be more generalizable. As such, this is a very pragmatic study, reflecting surgeons' practices and techniques internationally. A limitation of this study is the lack of advanced soft-tissue imaging to assess the integrity of the subscapularis tendon or computed tomography to assess healing of the osteotomy. Unfortunately, advanced imaging was out of the scope of the funding for this 188-patient study, and follow-up nonclinical computed tomography scans raised ethical concerns in the LTO group. Finally, specific physical examination findings to assess for subscapularis function, such as the belly-press test and liftoff test, were not uniformly assessed or recorded for this patient cohort. That being said, these physical examination maneuvers have been reported to have limited utility in the assessment of subscapularis integrity after TSA.[9]

Despite these limitations, this pragmatic study does provide value in that it assessed and compared early clinical, surgical, and radiographic outcomes of the subscapularis tenotomy, peel, and LTO when used with stemless shoulder arthroplasty in a large group of patients (N = 188). Specifically, as it pertains to validated outcomes, radiographic findings, and complications, no significant differences were found between subscapularis approach groups.

Conclusion

The results of this multicenter comparative analysis show that all 3 subscapularis management techniques (tenotomy, peel, and LTO) are effective and safe when used with stemless anatomic TSA at 2 years' follow-up.

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