



# Fixation Type Does not Affect the Learning Curve and Short-Term Radiographic Outcomes for Arthroscopic Anatomic Glenoid Reconstruction with Distal Tibia Allograft

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**Purpose:** The purpose of this study was to compare the learning curves and radiographic variables between screw and suture button fixation of the allograft for surgeons learning the all-arthroscopic anatomic glenoid reconstruction (AAGR) technique for anterior shoulder instability. We compared the surgical times of these two fixation techniques, as well as the graft placement in the vertical and medial-lateral directions. **Methods:** This was a retrospective review of patients who underwent AAGR for recurrent anterior shoulder instability. Start and end times were recorded for each procedure, and learning was assessed through the change in operative time over successive surgeries and by variability of operative time. Graft placement, in terms of vertical positioning, medial-lateral step formation, and obliquity of fixation (alpha angle), was evaluated using 3-dimensional CT scans at approximately 6 months postoperation. **Results:** A total of 43 patients were included in our study. Twenty-seven had screw fixation, and 16 had suture button fixation. The surgical duration of the button fixation technique was comparable to that of screw fixation ( $P = .72$ ), with no significant difference in the variability of surgical time in either cohort ( $P > .05$ ). Both groups showed similarly optimal vertical positioning of the graft onto the lower third of the glenoid ( $P = .89$ ). Desired obliquity of graft fixation was identified more frequently with button fixation ( $P < .001$ ). Both fixation methods provided clinically acceptable medial-lateral step formations, with suture-button fixation being significantly larger ( $P = .03$ ). **Conclusions:** Suture button fixation of the allograft is a potential alternative to screw fixation for the management of glenoid bone loss in recurrent anterior shoulder instability. The results of this study show that this method has a comparable learning curve, with a similar surgical duration, while not compromising the optimal accuracy of vertical and medial-lateral placement of the graft and achieves a superior alpha angle of fixation. **Level of Evidence:** Level III, retrospective cohort study.

## Introduction

In 2015, Wong and Urquhart<sup>1</sup> developed an all-arthroscopic anatomic glenoid reconstruction (AAGR) that was designed to overcome the technical challenges of

the arthroscopic Latarjet procedure—while maintaining minimal invasiveness—as well as overcoming the longer time requirement for open anatomic glenoid reconstruction. Furthermore, Wong and Urquhart<sup>1</sup> showed a decreased neurovascular risk in AAGR by sparing the subscapularis tendon, contributing to its excellent outcomes, as well as combining bony augmentation with Bankart capsulolabral repair for added stability. Additionally, Moga et al.<sup>2</sup> demonstrated that the AAGR procedure carries a shorter learning curve, has an overall faster surgical time, and has superior vertical allograft placement compared to the Latarjet technique.

Traditionally, fixation of the graft to the glenoid is performed through the use of metal screws. While screw fixation provides a stronger hold to the glenoid, Boileau et al.<sup>3</sup> reported that excessive screw obliquity may cause impingement with the humeral head, leading to the onset of osteoarthritis in the shoulder. Bone

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block malpositioning, bone-block fractures or nonunion, and hardware failures (such as screw bending, pullout, loosening, prominence in the joint, or breakage) are also screw-related complications.<sup>4,5,6,7</sup> Boileau also carried out a study that showed suture button fixation can be a safe and reliable alternative to screw fixation for the Latarjet procedure, obtaining predictable healing with excellent graft positioning, and avoiding hardware-related complications.<sup>3</sup> McNeil et al. introduced this fixation technique to the AAGR procedure and showed that nonrigid suture fixation may avoid reoperation for symptomatic hardware due to screw prominence and decrease the complexity of potential future surgery.<sup>8</sup> However, there is some uncertainty in load strength, as there have been no biomechanical studies assessing ultimate load-to-failure of suture fixation of the allograft in shoulder reconstruction procedures.<sup>9</sup> Similarly, as a consequence of the novelty of the procedure, suture button fixation has the potential to be technically challenging with an unknown learning curve.<sup>8,10</sup> Until now, there has been no gold standard method for the fixation of the graft during the AAGR procedure, and selection is mainly based on the surgeon's preference.

The purpose of this study was to compare the learning curves and radiographic variables between screw and suture button fixation of the allograft for surgeons learning the AAGR technique for anterior shoulder instability. We expected surgical time to be similar between these two fixation techniques, as well as the graft placement in the vertical and medial-lateral directions.

## Methods

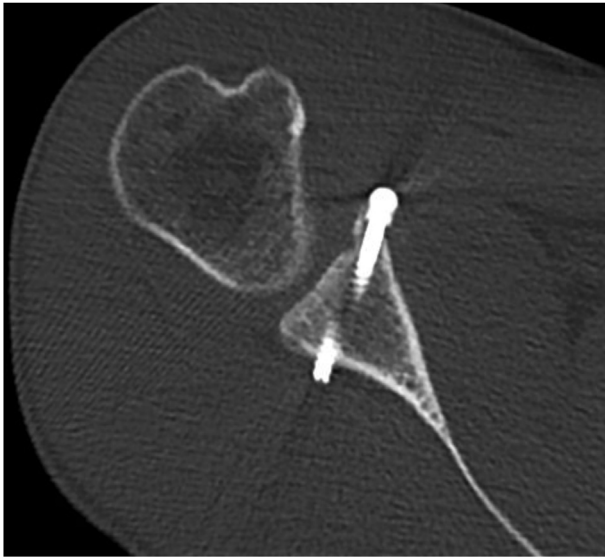
This study was a retrospective review of the patients who underwent AAGR by the senior author (I.W.) for anterior shoulder instability conducted at the Queen Elizabeth Health Sciences Center in Halifax, Nova Scotia. This study was approved by the Nova Scotia Health Authority Research Ethics Board. From the records, two groups of patients—those who had screw fixation of the distal tibial allograft and those who had suture fixation—were identified. Once candidates were identified, age, gender, side of operation, and date of surgery were collected in order to group for subsequent statistical analyses. Twenty-seven patients who underwent AAGR with screw fixation were previously included in a publication<sup>2</sup> comparing the learning curve of AAGR with arthroscopic Latarjet. This cohort of patients was the first set of consecutive patients operated on between 2012 and 2015 using the screw fixation technique (referred to as “early screw”). We also included the patients who underwent AAGR with suture button fixation between 2018 and 2019, which includes the first set of consecutive patients operated on following technique development. Finally, the patients who underwent screw fixation in the same time period

as the suture button cohort (2018-2019) were included in order to adjust for the effect of the surgeon's increased experience on surgical time and were not included in radiographic analyses (referred to as “late screw”). Exclusion criteria included patients with rotator cuff tears and/or multidirectional shoulder instability. Additionally, patients without postoperative computed tomography (CT) scans available were excluded. Each surgical cohort was divided into three clusters depending on the date of surgery: cluster 1 (first third of patients), cluster 2 (second third of patients), and cluster 3 (last third of patients).

Indications for AAGR were clinical and radiographic signs of shoulder instability with significant glenoid bone loss (defined as being >20%).<sup>11</sup> A standard work-up was performed preoperatively, including radiographic imaging, and glenoid bone loss was identified by preoperative three-dimensional (3D) CT scans using the diameter method. All surgical procedures were performed by the principal investigator (I.W.).

The learning curves were described as the change in operative time over successive procedures and the change in variability of operative time over successive procedures. To evaluate the learning curve of the surgical techniques, start and end times for screw and suture button fixation surgeries were recorded, and the duration was calculated. Start and end times were defined as incision and final closure times, respectively. These were organized into chronological order, and the mean surgical time was compared among clusters to assess learning at early, middle, and late stages. The variability of the surgical time was assessed within and between the clusters, where a lower variability of operative time was indicative of more advanced learning.

Postoperative CT scans obtained at approximately 6 months following surgery were reviewed for graft positioning on the native glenoid to assess learning of the techniques (Figs 1 and 2). All CT scans were acquired by using a 3D model, and image analysis was completed by two independent fellowship-trained surgeons. Using sagittal oblique images en face to the glenoid, vertical graft positioning was deemed by the middle of the graft centered over the lower, middle, or higher thirds of the glenoid bone.<sup>12</sup> With the glenoid shape resembling that of a pear, the lower third is the largest and contributes most to stability, and therefore, it is the ideal placement of the graft in order to recreate the native glenoid.<sup>13</sup> A transverse axial CT scan from the widest point of the glenoid was used to determine the alpha angle by calculating the angle between the axis of the fixation technique (screw or suture) and the glenoid fossa.<sup>12</sup> An alpha angle between 10° and 15° has been reported as the ideal placement of the graft.<sup>14</sup> Finally, medial-lateral step formation was measured at the allograft-glenoid junction.<sup>12</sup> Tangential lines (not



**Fig 1.** Axial CT scan at the widest point of the glenoid after arthroscopic anatomic glenoid reconstruction with screw fixation in a right shoulder treated for anterior shoulder instability.

shown) for both the graft and glenoid were drawn, with the distance between them representing step deformity. Positive values indicate a graft positioned lateral relative to the glenoid, while a negative value represents a graft placed medial to the glenoid. Ideally, there should be no step formation (i.e., flush with glenoid fossa); however, on the basis of previous literature, a medial step of 1-2 mm is acceptable.<sup>15</sup> Again, for each radiographic parameter, surgical cohorts were divided into clusters of patients (early, middle, and late thirds), and graft positioning was compared within and between clusters, as well as variability to assess learning.

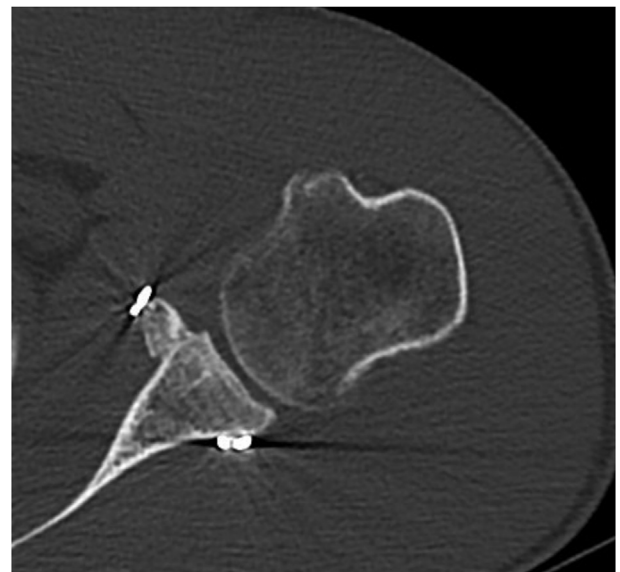
Two-tailed independent 2-sample *t*-tests were performed on surgical time and radiographic data to observe the difference between the clusters of screw and suture fixation of the allograft. Levene’s test for equality of variance was performed to see the variability of each parameter between the clusters of surgical cohorts. Patients with missing data would be excluded from the analysis. All tests were performed at a significance level of 95% ( $\alpha = .05$ ). Statistical analyses were performed with SPSS (IBM, version 25).

**Results**

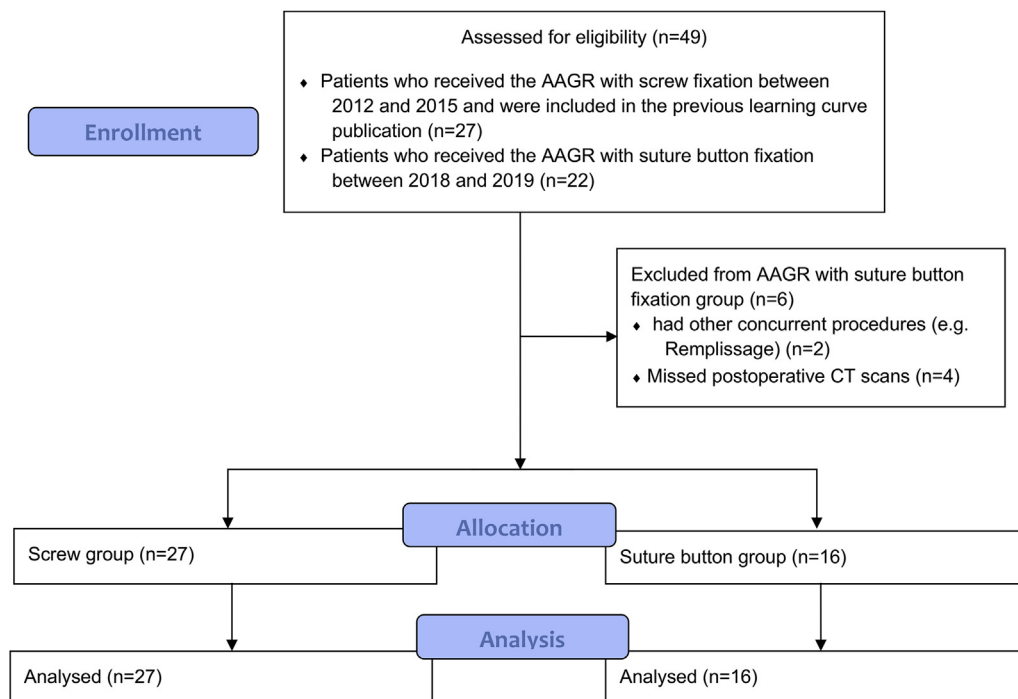
Forty-nine patients in total met the inclusion criteria, and six patients were excluded (Fig 3). Finally, 43 patients were included in the analysis. Among these, 16 patients underwent suture button fixation of the allograft, and 27 underwent screw fixation (early screw), with an additional 16 patients included in the late screw group, which were not included in radiographic analyses. Demographic information is summarized in

Table 1. There were no statistically significant differences between the groups regarding age, sex, or side of operation. The average time since operation for the early screw fixation group was significantly longer at  $6.7 \pm .7$  years, compared to  $2.7 \pm .4$  years in the suture button cohort and  $2.8 \pm .3$  years in the late screw group ( $P < .001$ ). Average time between surgery and follow-up CT scan was  $.5 \pm 0.4$  years and  $.5 \pm .5$  years for suture button and early screw fixation, respectively. The mean preoperative glenoid bone dimensions showed no statistically significant difference between the two groups ( $P = .772$ ), with suture button fixation being  $24.7 \pm 2.4$  mm, and that of the early screw group being  $24.9 \pm 2.3$  mm.

Table 2 compares the average length of the surgical operation between the suture button and early screw fixation methods by individual clusters, as well as by each technique’s cumulative average length. The mean surgical time for the overall suture button technique was found to be significantly faster than that of the screw method ( $P = .03$ ). Additionally, the mean surgical time for the second cluster of the suture button patient cohort was significantly faster than the corresponding screw cluster, at  $1.30 \pm .21$  hours compared with  $1.59 \pm .25$  hours, respectively ( $P = .03$ ). While the suture button fixation technique showed shorter operating times in general, neither cluster 1 nor cluster 3 had any significant difference in mean surgical time between fixation techniques. Furthermore, there was no significant difference in the variability in surgical time between the individual cohorts or between the overall mean operation lengths.



**Fig 2.** Axial CT scan at the widest point of the glenoid after arthroscopic anatomic glenoid reconstruction with suture button fixation in a left shoulder treated for anterior shoulder instability.



**Fig 3.** Flowchart of the selection of patients for the study.

**Table 3** compares the duration of surgery between the suture button fixation group and the screw group from the same time period (2018-2019). Both groups showed comparable operative times at  $1.35 \pm .22$  hours (button) and  $1.32 \pm .24$  hours (late screw), with no statistically significant difference found between overall means, cluster means, or in the variability between the two procedures.

Between the early screw fixation group (2012-2015) and the late screw fixation group (2018-2019), the late group had a significantly faster mean surgical duration at  $1.32 \pm .24$  hours compared with  $1.55 \pm .32$  hours ( $P = .01$ ) (**Table 4**). No significant differences were found between clusters in terms of mean duration, or in the variability in surgical times.

Although the intercluster differences were statistically insignificant within either group ( $P > .05$ ), there was a

marked reduction in operative time for both button and early screw fixation techniques over successive surgeries (**Table 5**). Additionally, there was no statistically significant difference with regard to the variability of surgical times in both the suture button and screw cohorts ( $P > .05$ ).

**Table 6** shows the comparison of the allograft vertical positioning upon assessment of CT scans at approximately 6 months postoperation for both cohorts. For the suture button fixation group, grafts were placed onto the lower third of the glenoid in 100% of the patients in the early cluster. This fell to 67% in the middle cluster, where two patients had grafts placed in the higher/middle third; however, this increased to 100% in the late cluster. No significant difference was found in terms of placement of the graft between the suture button fixation clusters ( $P =$

**Table 1.** Demographic Data of the Study Population

	Button (n = 16)	Early Screw (n = 27)	Late Screw (n = 16)	P Value*
Time after surgery (years)	$2.7 \pm .4$	$6.7 \pm .7$	$2.8 \pm .3$	<b>&lt;.001</b>
Age at surgery (years)	$36.1 \pm 16.0$	$27.9 \pm 11.7$	$34.6 \pm 14.6$	.055
Sex (F)	3 (19)	6 (22)	4 (25)	.913
Sex (M)	13 (81)	21 (78)	12 (75)	
Side (L)	9 (56)	15 (56)	9 (56)	.999
Side (R)	7 (44)	12 (44)	7 (44)	
Pre-op glenoid AP dimension (mm)	$24.7 \pm 2.4$	$24.9 \pm 2.3$		.772

Values are expressed as means  $\pm$  SD or percentage of total number (n).

\*Two-tailed independent two-sample *t*-tests were performed to identify differences between procedures. Bold values are statistically significant,  $P < .05$ .

**Table 2.** Comparison of Surgical Duration (in Hours) Between Procedures by Cluster

Procedure	Duration, hour			
	Cluster 1	Cluster 2	Cluster 3	Total
Button*	1.49 ± .25	1.30 ± .21	1.27 ± .15	1.35 ± .22
Early screw†	1.65 ± .42	1.59 ± .25	1.41 ± .23	1.55 ± .32
P value‡	.44	<b>.03</b>	.25	<b>.03</b>
P value§	.50	.63	.44	.33

Values are expressed as means ± SD.

\*Cluster 1, early (first 5 patients based on the date of surgery); Cluster 2, middle (middle 6 patients based on date of surgery); Cluster 3, late (last 5 patients based on date of surgery).

†Cluster 1, early first 9 patients; Cluster 2, middle 9 patients; Cluster 3, last 9 patients.

‡Two-tailed independent 2-sample *t*-tests were performed to identify differences between procedures. Bold values are statistically significant, *P* < .05.

§Levene’s test (equality of variance) was performed to assess the variability of duration among the procedures. Bold values are statistically significant, *P* < .05.

.15). For the early screw fixation group, 67% of cases in the first cluster group had grafts placed onto the lower third of the glenoid rim. This increased to 100% in the middle cluster and remained steady for the late cluster. There was a significant difference between clusters of the screw fixation group with regard to vertical placement of the allograft (*P* = .03). However, no significant difference was found between the suture button and early screw fixation method with regard to graft vertical positioning on the glenoid rim (*P* = .89).

Allograft positioning on the glenoid was also assessed by calculating the α-angle between the fixation axis and the glenoid fossa, with an angle between 10° and 15° being most desired (Table 7).<sup>14</sup> In the button fixation group, the angle of placement between clusters

improved following the first cluster of patients, whereas in the screw cohort, the angle increased after cluster 1 and remained outside the optimal range. The mean angle was significantly smaller in the button group than the early screw group in clusters 2 and 3 and fell within the desired range of 10°-15° (*P* = .004 and *P* = .006, respectively). Furthermore, the overall mean angle was significantly smaller in the suture button group than the screw group, also while remaining in the ideal range. Additionally, there was no significant difference in the variability in surgical time between the individual cohorts or between the overall mean operation lengths.

It was observed that there was no significant difference in the α-angle of allograft fixation between the clusters of the suture button group (*P* = .86–.99) (Table 8). In the early screw fixation group, the α-angle of the first cluster of patients was found to be significantly less than that of both cluster 2 and 3 (*P* = .02 and *P* = .04, respectively). Regarding the variability of the spread of the α-angles in each cluster, there was no statistically significant differences for either the button group (*P* = .61–.85) or the early screw group (*P* = .43–.96).

Medial-lateral (ML) step formation between the two fixation procedures was compared (Table 9), with a flush (0 mm) placement being ideal and a medial (negative) step of 1-2 mm being favorable over lateral placement.<sup>15</sup> The mean step in cluster 2 of the button fixation group was significantly larger than that of the early screw group at 2.9 ± 1.8 mm medially versus .5 ± 1.6 mm medially (*P* = .01), while no other significant difference was found between the clusters of fixation techniques. The overall mean step formation was significantly higher in the button group than the screw group (−1.3 ± 1.8 mm and −0.3 ± 1.1 mm,

**Table 3.** Comparison of Surgical Duration (in Hours) Between Procedures by Cluster

Procedure	Duration, hour			
	Cluster 1	Cluster 2	Cluster 3	Total
Button*	1.49 ± .25	1.30 ± .21	1.27 ± .15	1.35 ± .22
Late screw†	1.37 ± .20	1.31 ± .35	1.29 ± .14	1.32 ± .24
P value‡	.42	.95	.86	.72
P value§	.58	.31	.76	.83

Values are expressed as means ± SD.

\*Cluster 1, early (first 5 patients based on the date of surgery); Cluster 2, middle (middle 6 patients based on date of surgery); Cluster 3, late (last 5 patients based on date of surgery).

†Cluster 1, early first 5 patients; Cluster 2, middle 6 patients; Cluster 3, last 5 patients.

‡Two-tailed independent 2-sample *t*-tests were performed to identify differences between procedures.

§Levene’s test (equality of variance) was performed to assess the variability of duration among the procedures.

**Table 4.** Comparison of Surgical Duration (in Hours) Between Procedures by Cluster

Procedure	Duration, hour			
	Cluster 1	Cluster 2	Cluster 3	Total
Early screw*	1.65 ± .42	1.59 ± .25	1.41 ± .23	1.55 ± .32
Late screw†	1.37 ± .20	1.31 ± .35	1.29 ± .14	1.32 ± .24
P value‡	.08	.09	.30	<b>.01</b>
P value§	.32	.47	.37	.44

Values are expressed as means ± SD.

\*Cluster 1, early (first 9 patients based on the date of surgery); Cluster 2, middle (middle 9 patients based on date of surgery); Cluster 3, late (last 9 patients based on date of surgery).

†Cluster 1, early first 5 patients; Cluster 2, middle 6 patients; Cluster 3, last 5 patients.

‡Two-tailed independent 2-sample *t*-tests were performed to identify differences between procedures. Bold values are statistically significant, *P* < .05.

§Levene’s test (equality of variance) was performed to assess the variability of duration among the procedures. Bold values are statistically significant, *P* < .05.

**Table 5.** Difference in Surgical Time Among the 3 Clusters for Both Surgical Fixation Techniques

	Surgical Time Comparison	Time Difference, hour	<i>P</i> Value*	<i>P</i> Value†
Button	Cluster 1 vs 2	.19	.20	.75
	Cluster 1 vs 3	.22	.14	.30
	Cluster 2 vs 3	.03	.82	.34
	Cluster 1 vs 2 vs 3		.23	.53
Early screw	Cluster 1 vs 2	.06	.72	.42
	Cluster 1 vs 3	.24	.15	.30
	Cluster 2 vs 3	.18	.13	.67
	Cluster 1 vs 2 vs 3		.25	.45

\*Two-tailed independent 2-sample *t*-tests were performed to identify differences between clusters.

†Levene's test (equality of variance) was performed to assess the variability of duration among the clusters.

respectively;  $P = .03$ ). No significant difference was found in the variability of step formation between the individual cohorts or between the overall procedure means.

In the comparison of the difference in ML step formation between clusters, it was found that cluster 2 of the button fixation cohort was significantly larger than cluster 1 and cluster 3 ( $P = .01$  and  $P = .04$ , respectively) (Table 10). In the early screw fixation group, the mean difference in ML step formation in cluster 1 was shown to be significantly different than cluster 2 ( $P = .04$ ), with no other comparison between clusters showing any significant difference. Finally, there was no significant difference in terms of variability in the spread of step formation between the clusters of the button or screw fixation groups.

## Discussion

The principal findings demonstrated that suture button fixation has a comparable surgical time with minimal variability between clusters, provides optimal placement of the bone block to the glenoid in the vertical position, and achieves superior angling of fixation. Surgical techniques addressing bony pathology have traditionally used screws to secure the bone block onto

the anterior border of the glenoid rim. While this method has typically been the standard for graft fixation in shoulder reconstruction, a number of previous studies have described hardware-related complications as a major—if not the main—source of intraoperative and postoperative complications in these patients.<sup>4,5,6,7</sup> These include screw bending, pullout, loosening, prominence in the joint, or breakage, as well as bone block fractures. Also, screw obliquity has been a concern for humeral head impingement, leading to the onset of osteoarthritis.<sup>3</sup> As a result, reoperation for removal of symptomatic hardware has been reported to be a leading concern associated with screw fixation methods.<sup>5</sup>

Recently, however, nonrigid suture button fixation has gathered attention as a safe and reliable alternative.<sup>3</sup> Previous literature has shown that fixation using the button technique results in an osseous union rate of 95% between the graft and glenoid,<sup>9</sup> similar to that of screw fixation with a rate between 89% and 100%.<sup>12,16,17,18</sup> This excellent outcome may be a result of the increased surface area of the allograft in contact with the glenoid in the suture technique; instead of two 3.5-mm drill holes in the screw technique,<sup>1</sup> two 2.8-mm drill holes are used in button fixation.<sup>8</sup> Furthermore, while graft resorption is a common occurrence with both techniques due to use of distal tibial allograft, the nature of the suture button fixation technique obviates the symptomatic hardware seen in the screw fixation technique by avoiding screw protrusion into the joint capsule and surrounding structures.<sup>8</sup> Although load strength of the button has not been studied specifically in shoulder operations (AAGR or Latarjet), previous studies of anterior cruciate ligament (ACL) graft fixation and distal biceps fixation with cortical fixation devices (such as suture buttons) have shown ultimate load to failure of up to 440 N<sup>19</sup> and 864 N<sup>20</sup>, respectively, compared to 202 N with screws.<sup>21</sup> Another benefit of the suture button fixation is that the suture may be subsequently used to augment the Bankart repair, which may help patient outcomes and improve stability.<sup>8</sup> Although the learning curve has been previously studied for screw fixation in AAGR versus that of

**Table 6.** Comparison of Graft Position Among the 3 Clusters and Between Fixation Techniques

	Button, <i>n</i> (%)		Early Screw, <i>n</i> (%)		<i>P</i> Value†
	Lower Third	Higher/Middle Third	Lower Third	Higher/Middle Third	
Cluster 1	5 (100)	0	6 (67)	3 (33)	.89
Cluster 2	4 (67)	2 (33)	9 (100)	0	
Cluster 3	5 (100)	0	9 (100)	0	
<i>P</i> value*	.15		.03		

Bold values are statistically significant,  $P < .05$ .

\**P* value of comparison among clusters of respective cohorts.

†*P* value of comparison between button and screw techniques.

**Table 7.** Comparison of  $\alpha$ -Angle Between Procedures by Cluster

Procedure	$\alpha$ -Angle, degree			
	Cluster 1	Cluster 2	Cluster 3	Total
Button	9.8 ± 7.6	10.7 ± 8.4	10.7 ± 7.6	10.4 ± 7.4
Early screw	15.7 ± 7.5	25.3 ± 7.9	23.0 ± 6.0	21.4 ± 8.1
<i>P</i> value*	.19	<b>.004</b>	<b>.006</b>	<b>&lt;.001</b>
<i>P</i> value†	.77	.79	.41	.82

Values are expressed as means ± SD.

\*Two-tailed independent 2-sample *t*-tests were performed to identify differences between procedures. Bold values are statistically significant, *P* < .05.

†Levene’s test (equality of variance) was performed to assess the variability of duration among the procedures. Bold values are statistically significant, *P* < .05.

arthroscopic Latarjet, to the best of our knowledge, the learning curve of the button fixation in AAGR has been rarely described in the literature.

Although the suture button fixation method was shown to be significantly faster than the early screw method (Table 2), this clinical study demonstrated that the surgical time of the suture fixation procedure was comparable to that of the screw fixation method. As was suspected, the increase in surgical experience between the early screw group and the suture button fixation group may have been a contributing factor to the difference seen, as shown in Table 4, where the late screw group also had a significantly faster surgical time. In order to account for this, a comparison of the suture button fixation to the late screw group from the same time period (Table 3) was included. No significant difference was found, showing that the surgical times and learning curves are comparable. Also, the insignificant variability of operative time shown through Levene’s test represents advanced learning of the suture button technique (Table 5). This indicates that for a surgeon looking to adopt this procedure, whether already

**Table 8.** Difference in  $\alpha$ -Angle Among the 3 Clusters for Both Surgical Fixation Techniques

Alpha Angle Comparison		Mean Difference, degree	<i>P</i> Value*	<i>P</i> Value†
Button	Cluster 1 vs 2	-.86	.86	.61
	Cluster 1 vs 3	-.88	.86	.73
	Cluster 2 vs 3	-.02	.99	.83
	Cluster 1 vs 2 vs 3		.98	.85
Early Screw	Cluster 1 vs 2	-9.60	<b>.02</b>	.96
	Cluster 1 vs 3	-7.30	<b>.04</b>	.44
	Cluster 2 vs 3	2.28	.50	.43
	Cluster 1 vs 2 vs 3		<b>.02</b>	.67

\*Two-tailed independent 2-sample *t*-tests were performed to identify differences between procedures. Bold values are statistically significant, *P* < .05.

†Levene’s test (equality of variance) was performed to assess the variability of angle among the procedures. Bold values are statistically significant, *P* < .05.

familiar with the screw fixation technique or not, the suture button technique is quick to learn and become consistent. Just as Moga et al.<sup>2</sup> noted in a clinical study showing the more favorable learning curve of AAGR over arthroscopic Latarjet, fast and consistent surgical times are appealing for surgeons looking to adopt the method and means that the suture button fixation may be an alternative to screw fixation.

Further, the button technique demonstrated excellent rates of graft positioning to the inferior third on the glenoid rim, with the accuracy of placement reaching 100% of patients by the first cluster (Table 6). Although this rate fell in the second cluster with 2 patients with suboptimal placement, placement onto the lower portion reached 100% again by the third cluster. These results show that the suture fixation technique provides comparably optimal vertical positioning of the graft with that of the screw group, thus retaining the accuracy of placement.

Additionally, allograft angling in terms of the  $\alpha$ -angle was shown to be superior in the button fixation group (Table 7). Previous literature has shown that an  $\alpha$ -angle of 10°-15° is optimal for the fixation of the bone graft to the native glenoid.<sup>14</sup> The overall mean angle of the button group was shown to be 10.4° compared with that of the early screw group at 21.4°. None of the early screw cluster means fell within the optimal range (15.7°–25.3°), whereas clusters 2 and 3 of the button had a mean  $\alpha$ -angle of 10.7°, with only the early cluster falling below 10° at a mean of 9.8°. Although an improvement of the  $\alpha$ -angle was noted in the late screw group compared with the early screw group (means of 17.9 ± 10.4°), the mean still did not fall within the ideal range following the increased surgical experience. Furthermore, Table 8 shows that the  $\alpha$ -angle between clusters of the button fixation group remained more consistent with successive surgeries, compared to those of the early screw fixation group, where cluster 1 was significantly smaller than that of the other clusters. Again, increased consistency of a procedure is ideal for

**Table 9.** Comparison of Medial-Lateral Step Formation Between Procedures by Cluster

Procedure	Medial-Lateral Step Formation, mm			
	Cluster 1	Cluster 2	Cluster 3	Total
Button	-0.2 ± .5	-2.9 ± 1.8	-.5 ± 1.6	-1.3 ± 1.8
Early screw	.1 ± .9	-.8 ± .9	-.3 ± 1.4	-.3 ± 1.1
<i>P</i> value*	.46	<b>.01</b>	.78	<b>.03</b>
<i>P</i> value†	.48	.44	.65	.14

Values are expressed as means ± SD.

\*Two-tailed independent 2-sample *t*-tests were performed to identify differences between procedures. Bold values are statistically significant, *P* < .05.

†Levene’s test (equality of variance) was performed to assess the variability of step formation among the procedures. Bold values are statistically significant, *P* < .05.

**Table 10.** Difference in ML Steps Among the 3 Clusters for Both Surgical Fixation Techniques

	ML Step Comparison	Mean		
		Difference	<i>P</i> Value*	<i>P</i> Value†
Button	Cluster 1 vs 2	2.68	<b>.01</b>	.26
	Cluster 1 vs 3	.30	.70	.06
	Cluster 2 vs 3	-2.38	<b>.04</b>	.84
	Cluster 1 vs 2 vs 3		<b>.02</b>	.33
Early screw	Cluster 1 vs 2	.94	<b>.04</b>	.63
	Cluster 1 vs 3	.42	.46	.29
	Cluster 2 vs 3	-.52	.35	.39
	Cluster 1 vs 2 vs 3		.20	.44

\*Two-tailed independent 2-sample *t*-tests were performed to identify differences between procedures. Bold values are statistically significant,  $P < .05$ .

†Levene's test (equality of variance) was performed to assess the variability of step formation among the procedures. Bold values are statistically significant,  $P < .05$ .

surgeons, and this is highlighted as well by the lack of significant difference using Levene's test for the button group. The results of Tables 7 and 8 show that the button fixation technique may provide more reliable placement with regard to obliquity of fixation compared to screw fixation and may reduce the risk of osteoarthritis.<sup>3</sup> By using a drill guide, the suture button fixation technique achieves optimal and consistent placement of the graft.<sup>8</sup>

Medial-lateral step formation was deemed to be ideal when the graft is placed flush to the glenoid rim, with a 1-2 mm medial step being acceptable.<sup>15</sup> Although the early screw fixation group had a significantly smaller step (Table 9), both the screw and button fixation groups showed acceptable overall values (0.3 mm and 1.3 mm, respectively). As the screw fixation was shown to be more ideal by 1 mm, the difference seen may have been related to the small sample size and precision of measurements, or a result of the tensioning that is inherent with the suture fixation causing a shift in graft placement. It is felt that the theoretical benefit of eliminating hardware complications by using the suture button technique outweighs the rather small difference, as the medial-lateral placement of suture fixation still remains acceptable. The significantly larger mean medial step of the suture button group may warrant further investigation into the horizontal placement of the graft of this technique. However, there is some uncertainty in the literature regarding the acceptable medial step of shoulder reconstruction surgery, with Boileau et al. reporting a step of more than 5 mm to be deemed "too medial" clinically.<sup>3</sup> Regardless, data from clusters 1 and 3 between fixation groups show that screw and suture fixation can still achieve similar results, and although significantly larger than that of the screw group, the overall mean step remains clinically acceptable in this study. Finally, advanced learning was

again shown in the button fixation group demonstrated by Levene's test (Tables 9 and 10).

These allograft positioning results show that the practical results of the suture button fixation procedure demonstrate quick and precise learning of the technique. Also, it shows that accuracy was not compromised in the suture button group. Ultimately, the results of this study show that the button fixation technique can be an alternative to screw fixation in AAGR, carrying a quick learning curve with a comparable operation time, while maintaining accurate placement of the allograft. It is also important to note that in conjunction with the results from Moga et al.,<sup>2</sup> these results show that the suture button fixation in AAGR, like screw fixation, can also be an alternative to arthroscopic Latarjet, with a quicker operation time and shorter learning curve. This may be of particular importance to orthopedic surgeons looking to find alternatives to the technically challenging arthroscopic Latarjet technique, while avoiding the risk for symptomatic hardware from screw fixation and decreasing the complexity of possible reoperations.

Although no statistically significant difference was found between fixation groups regarding preoperative glenoid dimensions or age, which would suggest that conditions prior to surgery did not affect surgical times, analysis of preoperative patient-reported outcome scores would have allowed that conclusion to be drawn. It is also important to mention that the differences in radiographic results may have been a consequence of the increased surgical volume, and, therefore, experience, that occurred between the two procedures. Although the covariate effect of the increased surgical experience was accounted for with the surgical duration data by the inclusion of the late screw group, radiographic data of the late screw group were not included in this study, as the focus was on the early radiographic data between the suture button and early screw group. That being said, all surgeries were performed by a single surgeon who regularly performs AAGR with screw fixation. Thus, the radiographic results for button fixation represent the transition to this novel technique. This may further emphasize the promising results of suture button fixation showing that it may still provide reliable placement of the graft. However, further studies with recent screw fixation procedures (as well as including patient-reported outcome scores preoperatively), may provide more reliable results. Another strength of this study is that both operative time and radiographic results were evaluated together, as opposed to separately. Further studies into the preoperative and postoperative clinical outcomes, with an increased sample size, are required to assess long-term outcomes of button fixation compared to screw fixation.



**Limitations**

A limitation of this study was the retrospective study design, where the sample size is not predetermined and nonrandomized; patients that met inclusion and exclusion criteria comprised the study population, resulting in a relatively small sample size. Additionally, the increased surgical experience that was gained between cohorts may have brought transferable learning that confounded the results of the later groups, in terms of both learning curve and practical results.

**Conclusion**

Suture button fixation of the allograft is a potential alternative to screw fixation for the management of glenoid bone loss in recurrent anterior shoulder instability. The results of this study show that this method has a comparable learning curve, with a similar surgical duration, while not compromising the optimal accuracy of vertical and medial-lateral placement of the graft and achieves a superior  $\alpha$ -angle of fixation.

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