Comparison of coracoid graft position and fixation in the open versus arthroscopic Latarjet techniques: A cadaver study.

ABSTRACT

Background: Since the description of the arthroscopic Latarjet technique, the discussion about superiority of open or arthroscopic procedure has arisen. The appropriate placement of the coracoid graft (CG) on the anterior glenoid neck was reported to be the most important step of the Latarjet procedure.

Purpose: To verify if there are differences in the parameters that may affect the final position and fixation of CG obtained from open and arthroscopic Latarjet techniques.

Study Design: Descriptive laboratory study.

Methods: Twenty fresh-frozen human paired cadaveric shoulders specimens had been randomly distributed in two surgery groups (open group, OG; arthroscopic group, AG) with 10 specimens in each. Two surgeons, each with experience performing open and arthroscopic Latarjet techniques, executed these procedures in each of the respective groups. After surgery, a computerized tomography scan was performed. The surgical time, the position of each CG, a series of variables that might affect the CG fixation and the level of the subscapularis split, were evaluated.

Results: The mean surgical time was significantly higher in the AG (mean, 26 min for OG and 57 min for AG). Three intraoperative complications (30%) were identified in the AG consisting of graft fractures. The CG was determined to be in an optimal cranial-caudal position in 90% of specimens of OG and in 44% of AG (Fisher $p = 0.057$). In both groups, the CG was placed in an optimal medial-lateral position in all specimens. In the OG, the degree of parallelism between the major axes of the glenoid surface and CG was significantly greater than in AG (mean, 3.8º for OG and 15.1º for AG). No significant differences were observed in superior and inferior screws orientation between both groups. In the longitudinal and transversal directions, significant differences were found in the centering of the superior screw, being in the OG closest to the ideal point that in the AG. The location where the longitudinal subscapularis split were performed was significantly higher in the AG.

Conclusions: The open Latarjet technique requires less surgical time to complete the procedure, presents a lower number of intraoperative complications, and allows a more adequate placement of the CG, a better centering of the screws and a subscapularis split closest to the ideal position.

Clinical relevance: The reported benefits of the arthroscopic Latarjet technique seem less clear if we take into account the added surgery time and complications.

Keywords: Shoulder instability; Open Latarjet technique; Arthroscopic Latarjet technique; Graft positioning; Graft fixation; Cadaver study.

What is known about the subject: The appropriate placement of the coracoid graft (CG) on the anterior glenoid neck was consistently reported to be the most important step of the Latarjet procedure in order to achieve glenohumeral stability and to avoid any short- or long-term complications. Screw placement is also believed to be critical and could influence the outcome.

What this study adds to existing knowledge: No clear information exists about the efficacy of open and arthroscopic Latarjet procedures in terms of correct CG placement. To our knowledge, no reports have been published that relate the position of screws in the longitudinal and transverse axes of the CG with incidence of complications.

INTRODUCTION

The Latarjet coracoid bone block stabilization[28] is one of the main procedures used for the treatment of recurrent anterior shoulder instability, particularly with significant bone loss.[38] The results of this technique are excellent, with a low recurrence rate of instability in most series (lower than 5%) and with optimal functional results.[4] Nevertheless, since the description of arthroscopic technique in 2007,[5,27] the number of arthroscopic Latarjet stabilizations has been increasing and the discussion about superiority of one procedure over the other has arisen.

The appropriate placement of the coracoid graft (CG) on the anterior glenoid neck was consistently reported to be the most important step of the Latarjet procedure in order to achieve glenohumeral stability and to avoid any short- or long-term complications.[4,33] However, the effectiveness of the Latarjet technique does not depend only on the position of the CG. Screw placement is also believed to be critical and could influence the outcome.[37] Proper CG fixation is necessary to accommodate the axial and shear forces present in the glenohumeral joint and avoid fixation failure, which can lead to graft nonunion, migration, or recurrent instability.[9] However, no clear information exists about the efficacy of open and arthroscopic Latarjet procedures in terms of correct CG placement. To our knowledge, no reports have been published that relate the position of screws in the longitudinal and transverse axes of the CG with incidence of complications.

The goal of this study is to establish if there are differences in the parameters that may affect the position and the fixation of the CG. We hypothesize that the open compared to the arthroscopic Latarjet technique allows a more adequate placement of the CG in relation to the glenoid cavity and a tendon tenorrhaphy of the subscapularis muscle closest to the ideal position. We also hypothesize that there are no significant differences between both techniques in terms of the orientation and centering of the screws.

METHODS

The study was performed in accordance with the Declaration of Helsinki. Twenty fresh-frozen human paired cadaveric shoulders specimens were used for this study (4 male and 6 female; age between 69 to 85 years). The specimens belonged to the Department of Anatomy and Embryology of our Institution and were obtained following the legal procedures governing the donation of bodies. None of the donors had a clinical history of medical or surgical pathology of the shoulder joint. The 20 shoulders were randomly divided into two groups: 1) the open surgical group (OG), labelled 1 to 10 (4 females and 6 males), underwent the open surgical technique; 2) the arthroscopic surgical group (AG), labelled 11 to 20 (4 females and 6 males), underwent arthroscopic surgical technique (Table 1). All of the shoulders were placed in the "simulated beach chair position”. To guarantee that the open and arthroscopic procedures were carried out in accordance with the standard technique, one surgeon (surgeon 1) performed all of the open procedures and a different surgeon (surgeon 2) performed all of the arthroscopic procedures, each one with proven experience in the technique performed. Surgeon 1, with 25 years of practical experience as an orthopedic surgeon and with more than 250 open Latarjet procedures done before the study, performs more than 75 shoulder stabilizations / year and 25 to 30 open Latarjet procedures / year. Surgeon 2, with 17 years of practical experience as an orthopedic surgeon and with more than 60 arthroscopic Latarjet procedures done before the study, performs more than 50 shoulder stabilizations / year and 15 to 20 arthroscopic Latarjet procedures / year". In both groups, two 3.75 mm full threaded titanium cannulated screws were used.

TABLE 1

Epidemiology of the specimens selected for the study and their distribution in groups.

Group 1	***Specimen***	***Sex***	***Side***	***Group 2***	***Specimen***	***Sex***	***Side***
	1	*Female*	*Right*		*11*	*Male*	*Right*
	2	*Female*	*Left*		*12*	*Female*	*Right*
	3	*Female*	*Right*		*13*	*Male*	*Right*
	4	*Male*	*Left*		*14*	*Male*	*Right*
Open Latarjet	*5*	*Male*	*Left*	***Arthroscopic Latarjet***	*15*	*Male*	*Right*
	6	*Female*	*Left*		*16*	*Female*	*Right*
	7	*Male*	*Left*		*17*	*Male*	*Left*
	8	*Male*	*Right*		*18*	*Female*	*Left*
	9	*Male*	*Left*		*19*	*Male*	*Left*
	10	*Male*	*Right*		*20*	*Female*	*Left*

Open Latarjet technique

This technique was performed on the OG by the same surgeon with modifications to the classical technique that was described by Patte et al.[34] We used both the basic surgical instruments in addition to specific ones that were designed by Dr. Stephen Burkhart and are distributed by Arthrex (Arthrex Inc., Naples, FL).

Arthroscopic Latarjet technique

This technique was performed on the AG by the same surgeon with modifications to the classical technique that was described by Lafosse & Boyle.[25] In addition to the equipment that were necessary to perform the arthroscopic approach, specific instruments that were designed by Dr. Lafosse and distributed by De Puy Mitek company (De Puy Mitek, Wokingham, UK) were also used for the arthroscopic Latarjet.

Surgical time

The surgical time used to complete the procedure was measured from the first incision until the procedure was completed just prior to closing.

Radiological analysis

During the first 24 hours after the interventions, a CT scan was performed (Toshiba Aquilion multi-detector CT with 64 detectors -TSX-101A-). A volumetric configuration was made in the axial plane with the bone and soft tissue reconstructions at a thickness of 0.5 mm (standardized diagnostic for this equipment). Subsequently, in postprocessing steps, orthogonal reconstructions were made in the coronal and sagittal planes, in addition to 3D reconstructions using a volume rendering technique. Toshiba's Vitrea software (version 4.1.14.0), Advantage Windows (General Electric healthcare, Milwaukee, WI, version AW 4.3_05) and OsiriXTM (OsiriX Switzerland, image processing software, version 7.0 32-bit) were used to analyze the images.

The metric analysis of the radiological parameters was carried out by a radiologist outside the study, who did not know the type of technique applied to each specimen.

Position measurements

1) Cranial-caudal position of the CG.

This position was evaluated in a sagittal CT view of the glenoid (en-face view) that was obtained coinciding with the greater length of the CG. The clock position system was used according to the technique described by Kraus et al.[21] (Fig. 1). The CG height position was determined to be optimal between 2 and 5 o'clock a right shoulder assumed. When the CG's upper end is above the 2 o'clock point, it is considered to be a superior position. Conversely, it is considered an inferior position when the lower end of the CG is below the 5 o'clock point.

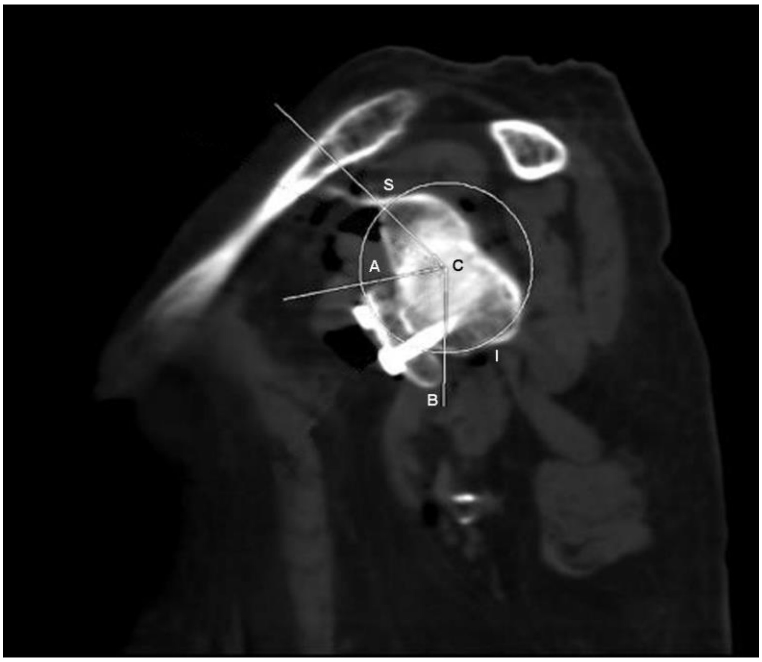

Figure 1. Measurement of the cranial-caudal position of the CG. The coracoid graft presents a satisfactory height position between 10 and 7 o’clock position on a left shoulder. *Circle* around glenoid; *A*, upper end of the CG; *B*, lower end of the CG; *C*, centre; *I*, infraglenoid tubercle; *S*, supraglenoid tubercle.

2) Medial-lateral position of the CG.

This position was evaluated according to the technique described by Kraus et al.[20] Initially, a sagittal CT view of the glenoid was obtained. Kraus et al. defined the glenoid heights of 25%, 50%, and 75% starting from the most superior aspect of the glenoid.[20] In our case, to be more precise, we divided the glenoid height into 10 equal parts. Measurements were then taken in the corresponding axial CT view. The most prominent point was used as the reference for the measurement. A line was drawn alongside the glenoid. The anterior and posterior subchondral rims of the glenoid were used as reference points. In relation to the line drawn between the reference points, the graft was judged to be lateral, flush, or medial (Fig. 2). The value, in millimeters, was negative if the CG was medialized with respect to the glenoid and positive if lateralized. We considered that accurate positioning of the bone block was reached when values of medialization and lateralization were within -5 mm and +3 mm, respectively, as previously determined and discussed later.

Figure 2. Measurement of the medial-lateral position of the CG.

3) Angle between the major axes of the glenoid and CG.

This measurement indicates the degree of parallelism between the CG and the glenoid surface. In the sagittal plane, two images are superimposed: one taken at the level of the major axis of the glenoid and another taken at the level of the major axis of the CG. The superposition of these two images allows us to measure this angle (Fig. 3).

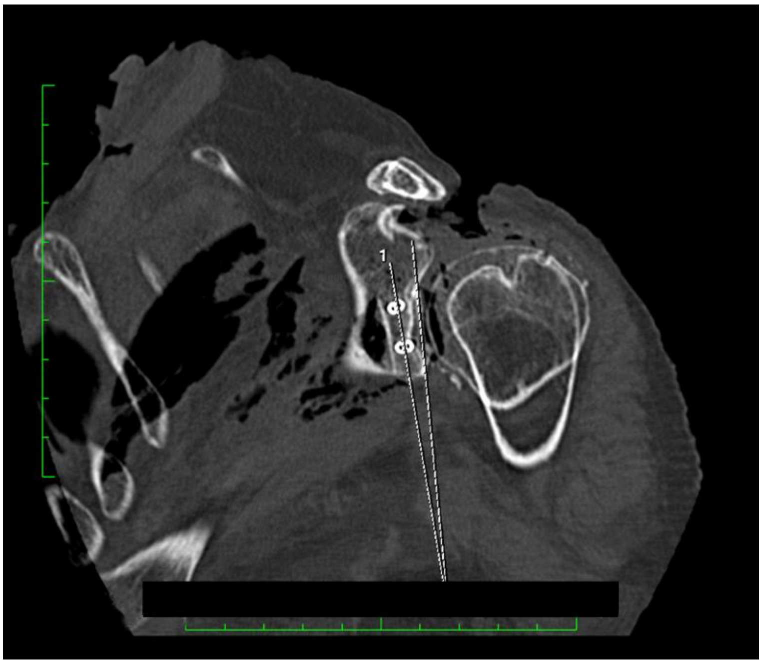

Figure 3. Superimposition of two sagittal CT images to measure the angle between the major axes of the glenoid and the coracoid graft.

Fixation measurements

All measurements of parameters that might affect the coracoid graft fixation have been performed in a sagittal CT view, except the angles measurement of the superior and inferior screws with respect to the glenoid surface obtained in the axial view.

1) Measurement of the angles of the superior (α1) and inferior (α2) screws with respect to the glenoid surface. The surface of the glenoid subchondral bone is taken as reference, drawing a line tangent to this surface that passes through the anterior and posterior rims of the glenoid. The angle of the superior and inferior screws was determined as the angle between the anterior line and the screw axis (Fig. 4).

Figure 4. Measurement of the angle of the superior screw with respect to the surface of the glenoid subchondral bone.

2) Distances from the superior screw to the lateral (A1) and medial (A2) borders of the CG (Fig. 5).

3) Width of the CG at the level of the superior screw (A) (Fig. 5A).

4) Distance from the inferior screw to the lateral (B1) and medial (B2) borders of the CG (Fig. 5).

5) Width of the CG at the level of the inferior screw (B) (Fig. 5A).

6) Distance from the superior screw to the osteotomy line (L1) (Fig 5).

7) Distance from the inferior screw to the CG tip (L2) (Fig. 5).

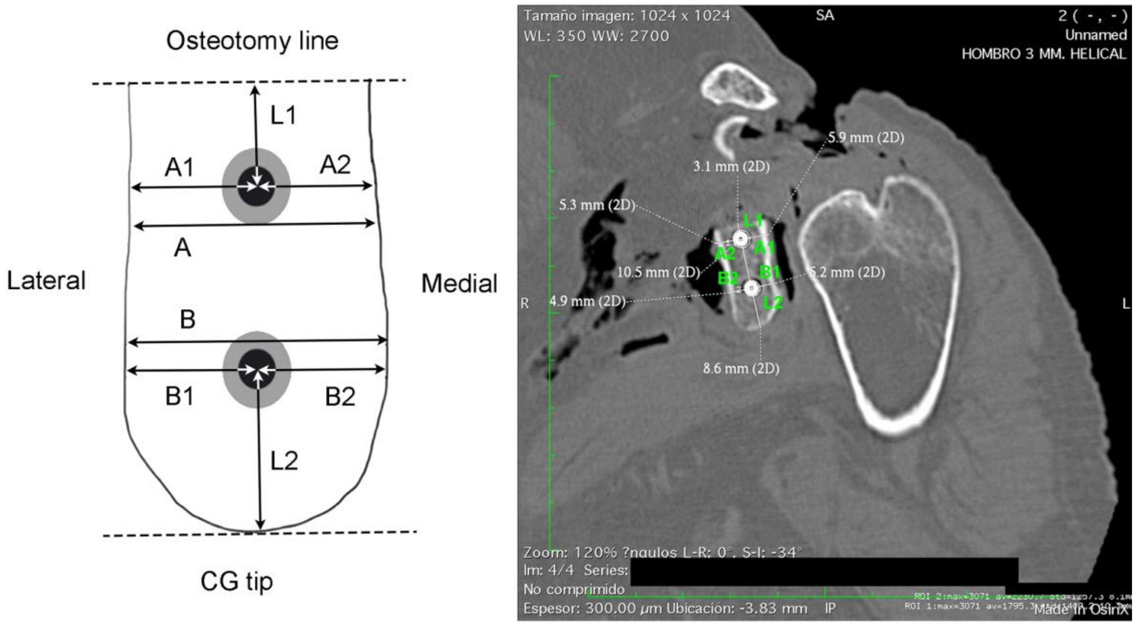

Figure 5. Measurement of the distances of the screws to the limits of the coracoid graft (CG). Width of the CG at the level of the superior (A) and inferior (B) screws. Distances from the proximal screw to the lateral (A1) and medial (A2) borders of the CG. Distances from the distal screw to the lateral (B1) and medial (B2) borders of the CG. Distance from the proximal screw to the osteotomy line (L1). Distance from the distal screw to the vertex of the CG (L2).

Level of the subscapularis split

The level of the subscapularis split has been calculated by dividing the distance between the upper border of the subscapularis and the opening point by the total width of the tendon. This location, defined as optimal, corresponds to the junction of the middle and inferior thirds (60%).[39]

Statistical analysis

The normality of the qualitative data distribution was studied with the Fisher's exact test. The normality of the quantitative data distribution and the homogeneity of variances were studied first with the Shapiro-Wilk and Levene tests, respectively. After checking that both conditions were met, the comparison of means was statistically analyzed with the Student's t-test. For the statistical analysis of the data, the IBM SPSS Statistics Base 25.0 program was used, with statistical significance set at 95% ($p \leq 0.05$).

RESULTS

In the OG, 10 specimens were used, while in the AG, only 9. One of the AG specimen suffered a longitudinal fracture in the coracoid process when the osteotomy was performed, rendering it unusable for grafting (Fig. 6A).

Surgical time

The surgical time used to complete the procedure in the OG (mean, 26 minutes; range, 29-34.3) was significantly lower ($p = 0.001$) than in the AG (mean, 57 minutes; range, 56-69).

Complications

There were no significant differences in the intraoperative complications ($p = 0.211$), which was 0 for the OG and 3 for the AG. The 3 intraoperative complications (30%) identified in the AG consisting of graft fractures. 1)

Specimen 13: at the time of the coracoid osteotomy, a longitudinal fracture passed through the screws and reached the apex of the same. The procedure could not be completed (Fig. 6A). 2) Specimen 18: a displaced fracture affecting the upper edge of the glenoid was seen in the CT scan and extended distally to the upper edge of the anchor area of the CG (Fig. 6B). 3) Specimen 19: a longitudinal fracture was identified between the graft fixation screws (Fig. 6C). Fractures of specimens 18 and 19 were not identified during the arthroscopic procedure and were visualized during radiological analysis.

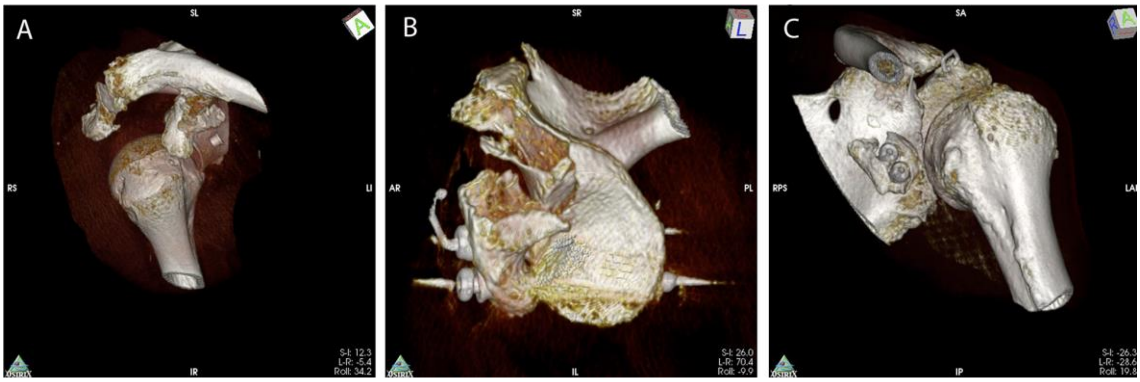

Figure 6. (A) Fracture of the coracoid process at the time of the osteotomy. (B) Fracture of the upper edge of the glenoid. (C) Longitudinal fracture of the CG between the fixation screws.

Cranial-caudal position of the CG

We have observed differences between the two groups that did not reach statistical significance (Fisher $p = 0.057$). In the OG, 9 were in the optimal position and 1 was placed inferiorly. In the AG, 4 were optimal, 1 was superior and 4 were inferior.

Medial-lateral position of the CG

In the medial-lateral position of the CG, no significant differences were found between the two groups ($p = 0.243$). The CG was placed in a position flush with the glenoid rim in all operated specimens. However, there was a tendency to place the CG slightly lateral in the OG (mean, 1.1 mm; range, -0.07 to 1.6) versus the AG, in which it was placed discretely medially (mean, -1.67 mm; range, -2.8 to 2.24).

Angle between the major axes of the glenoid and the CG

There were significant differences between the two groups ($p = 0.001$).
The CG placed in the AG presented a significantly greater degree of inclination with respect to the surface of the glenoid than those placed in the OG. In the OG it was 3.8º on average (range, 1-8), whereas in the AG it was 15.1º on average (range, 9.5-21.5).

Measurement of the orientation and distances of the screws to the limits of the coracoid graft (Table 2)

No significant difference was found in superior (p = 0.466) and inferior ($p = 0.156$) screws orientation between both groups. The mean angle of inclination of the superior screw in relation to the glenoid was 6.3° for OG (range, 3.0 - 11.3) and 6.7° for AG (range, 4.9 - 14.3). In the case of the inferior screw, the mean angle of inclination was 5.8° for OG (range, 3.3 -9.9) and 10° for AG (range, 6.1 - 16.4).

In the transverse direction, significant differences were found in the centering of the superior screw; in the AG a significant tendency was observed to place the superior screw closer to the medial border of the CG (p = 0.022). No significant differences were found in the centering of the inferior screw with respect to the medial (p = 0.156) and lateral (p = 0.156) borders of the CG.

In the longitudinal direction, significant differences were found in the centering of the superior screw (p = 0.003), being in the OG closest to the ideal point that in the AG. In the AG, a significant tendency was observed to place the superior screw farther from the osteotomy line. No significant differences were found in the centering of the inferior screw, being closest to the ideal point.

TABLE 2

Results of the statistical analysis of quantitative fixation data studied.

	OG median (interquartile range)	**AG** median (interquartile range)	**p-value**
α1, º	6.3 (3-11.3)	6.7 (4.9-14.3)	0.466
α2, º	5.8 (3.3-9.9)	10 (6.1-16.4)	0.156
A1, mm	0.5 (0.44-0.52)	0.58 (0.56-0.63)	**0.002**
A2, mm	0.5 (0.49-0.57)	0.42 (0.4-0.51)	**0.022**
B1, mm	0.5 (0.49-0.52)	0.53 (0.47-0.59)	0.156
B2, mm	*0.5 (0.48-0.51)*	*0.47 (0.41-0.53)*	*0.156*
L1, mm	*5.9 (4.63-6.5)*	*8.4 (7.15-11.8)*	***0.003***
L2, mm	*6 (5.8-7)*	*6 (4-9)*	*0.672*

AG, arthroscopic surgery group; OG, open surgery group; α1, angle of the superior screw with respect to the glenoid surface; α1, angle of the inferior screw with respect to the glenoid surface; A1, distance from the superior screw to the lateral border of the CG; A2, distance from the superior screw to the medial borders of the CG; B1, distance from the inferior screw to the lateral border of the CG; B2, distance from the inferior screw to the medial borders of the CG;

L1, distance from the superior screw to the osteotomy line; L2, distance from the inferior screw to the vertex of the CG.

Level of the subscapularis split

There were significant differences in the location where the longitudinal subscapularis split was performed ($p = 0.001$). In the OG, the subscapularis split was located in the optimal position in all specimens, with 60% being the average (range, 60%-66%). In the case of AG, it was close to the midpoint of the tendon, with 53% being the average (range, 50%-55%).

DISCUSSION

Our results confirm our hypothesis that the open Latarjet technique allows a more adequate placement of the CG and a tendon tenorrhaphy of the subscapularis muscle closest to the ideal position. They also confirm that there are no significant differences between both techniques in terms of the orientation of the screws. However, open Latarjet technique allows a better centering of the screws with respect to the longitudinal and transverse directions.

Our results show that the mean surgical time used to complete the procedure in the OG (26 minutes) was significantly lower than in the AG (57 minutes).

Gracitelli et al, in a cadaveric study on the arthroscopic Latarjet technique, reported a mean surgical time of 137 minutes, more than twice the time used in our study. This difference may be partly due to the fact that four orthopedic shoulder surgeons carried out the procedures, with experience in performing arthroscopies and in the open Latarjet surgery, but without previous experience with the performance of the arthroscopic Latarjet procedure.[14] In our study, the surgeon 2, with proven experience in the arthroscopic Latarjet technique, performed all arthroscopic procedures.

In recent comparative studies between open and arthroscopic Latarjet technique performed in patient,[13,40] the surgical time used in both procedures is greater than in our study in cadaver, although the time applied in the open Latarjet technique is still significantly lower. This greater surgical time used, maybe explained by the fact that there are less technical difficulties in the cadaver such as bleeding or medical concern due to the spread of extravasated fluid to the neck and the hemithorax.

According to a systematic review of the literature,[29] several authors stressed that the long-term clinical and radiologic outcome of the Latarjet procedure largely depends on the accurate positioning of the CG in relation to the glenoid margin, in both the axial and sagittal planes.[4] Precise CG placement remains a challenging task.

In general, it is believed that in the sagittal plane the optimal cranial-caudal position of the CG should be between 2 and 5 o'clock.[18,19,27] Too high or too low, a CG positioning may lead to relapse, as dislocation may occur below or above the CG.[2]

In our study, with respect to the cranial-caudal position, of the 10 specimens from the OG, only in 1 was the CG was considered misplaced, inferiorly (10%). This incidence corresponds to that of other published series in which CT scan has been used to evaluate the position of the CG.[7,12] However, of the 9 specimens from the AG, 5 were considered misplaced in the cranial-caudal direction (55.6%), 4 inferiorly and 1 superiorly. This percentage is very high when compared with the 8.2%-20% obtained in other series.[18,27,33,35,40] These discrepancies could be explained by several factors such as sample size, protocol used for CT scan analysis, or difference in execution of surgical technique. Our results corroborate the fact that the cranial-caudal positioning of the CG with respect to the glenoid is more difficult by arthroscopic surgery.

The greatest difficulty in arthroscopic surgery is conditioned by the level of the subscapularis split and by the use of an anterior and medial portal vision. With an open approach, direct visualization of the subscapularis muscle fibers allows a precise horizontal split, typically performed at the inferior third of the muscle.[39] However, with an arthroscopic approach, visualization of the entire subscapularis is more challenging due to the arm position, the inability to see the subscapularis muscle belly intra-articularly, and the fact that the side view obtained with the 30º or 70º arthroscope may lead to distortion.[22]

In our study, there were significant differences in the location where the longitudinal subscapularis split was performed. In the OG, the subscapularis split was located in the optimal position in all operated specimens, being 60% on average, whereas in the case of AG it was close to the midpoint of the tendon, being 53% on average. A high split location makes the procedure more difficult.[1,15] Therefore, the level at which the subscapularis split is performed can condition the proper placement of the CG, justifying the differences found by us between OG and AG.

In the axial plane, it is believed that accurate medial-lateral position of the CG should be within -4 or -5 mm medially and +2 or +3 mm laterally.[7,10,13,29,32,40]

Placing the CG too medially could result in an increased rate of recurrence.[17,30] Conversely, too lateral CG placement is considered to be associated with a higher incidence of degenerative changes.[16,17,24]

The results found in the literature about the medial-lateral position of the CG evaluated by CT scan are diverse.[11,18,19,31,32,40] In our study, the lateral-medial position of the CG in all specimens was within the margins considered acceptable by most authors. No significant differences have been found between OG and AG. However, there was a tendency to place the CG slightly lateral in the OG (mean, 1.1 mm) compared with the AG, in which it was placed discretely medially (mean, -1.67 mm).

A parameter that has not been taken into account in published works thus far is the degree of parallelism of the CG with respect to the surface of the glenoid (Fig. 7). We have not found any reference in the literature on how to measure this parameter. In our study, we have verified that the degree of parallelism of the CG with respect to the glenoid is significantly greater in the OG ($p = 0.000$). Considering that the optimum degree of parallelism is 0º, in the OG it was 3.8º on average, whereas in the AG it averaged 15.1º. The greater angulation of the distal end of the CG in AG may be due to the higher position and smaller amplitude of the subscapularis split, to which the retropulsion of the scapula is added. The medialized position of the distal end of the CG could decrease the dynamic reinforcement of the conjoined tendon of the anteroinferior part of the capsule (musculotendinous block), since the conjoined tendon would also see its position medialized with respect to the apex of the CG. In addition, the lack of flush at the anteroinferior level would decrease the effective surface area of the glenoid (bone block).

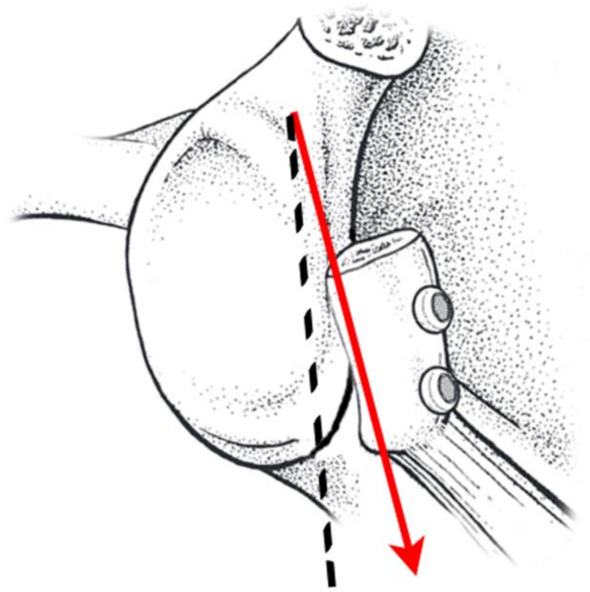

Figure 7. Specimen of the arthroscopy surgery group in which the coracoid graft presents an inclination of 13º with respect to the surface of the glenoid.

The effectiveness of the Latarjet technique does not depend only on the position of the CG. Screw placement is also believed to be critical and could influence the outcome.[37] The goal is to place the screws parallel to the glenoid articular surface to obtain the best compression and stability. Excessive screw obliquity may cause impingement with the humeral head, leading to rapid onset of osteoarthritis of the glenohumeral joint.[8] In an anatomic study, Lädermann et al demonstrated that a safe zone for placement of screws to avoid iatrogenic injury was within 10º relative to the face of the glenoid.[23] More recently, the position of the screw was defined as overangulated when α angle was >25°.[6,11]

Here we show that there is no significant difference in superior and inferior screws orientation between both groups. The mean angle of the superior screw in relation to the glenoid was 6.3° for OG and 6.7° for AG. In the case of the inferior screw, the mean angle was 5.8° for OG and 10° for AG.

These results are within the recommendation of Lädermann et al of less than a 10º angle.[23]

The angles we obtain in this work were slightly more parallel than the angles reported in recent studies on the open technique, arthroscopic technique and comparative studies.[11,13,18,19,26,32,35,36,40] All these results remained within the recommendations of Lädermann et al of 10º and of Boileau et al. of 25º.[6,23]

To our knowledge, no reports have been published that relate the position of screws in the longitudinal and transverse axes of the CG with incidence of complications.

In our results, open Latarjet technique allows for a better centering of the screws with respect to the longitudinal and transverse directions. In the OG the centering was closest to the ideal point that in the AG.

In the longitudinal direction, a significant tendency to place the superior screw farther from the osteotomy line was observed in the AG. This placement could be justified since the holes in the AG are made when the coracoid is still attached to the rest of the scapula. This increase of distance is due to avoid the risk of fracture releasing stress between the osteotomy and the proximal screw. When there is a fixed distance between both screws, trying to move the superior screw away from the osteotomy line causes a more distal position of the inferior screw.This position can influence the fixation of the CG. If the inferior screw is located too close to the vertex of the coracoid it may not make enough compression or, in extreme cases, it may not obtain adequate fixation at the lower segment of the glenoid (Fig. 8).

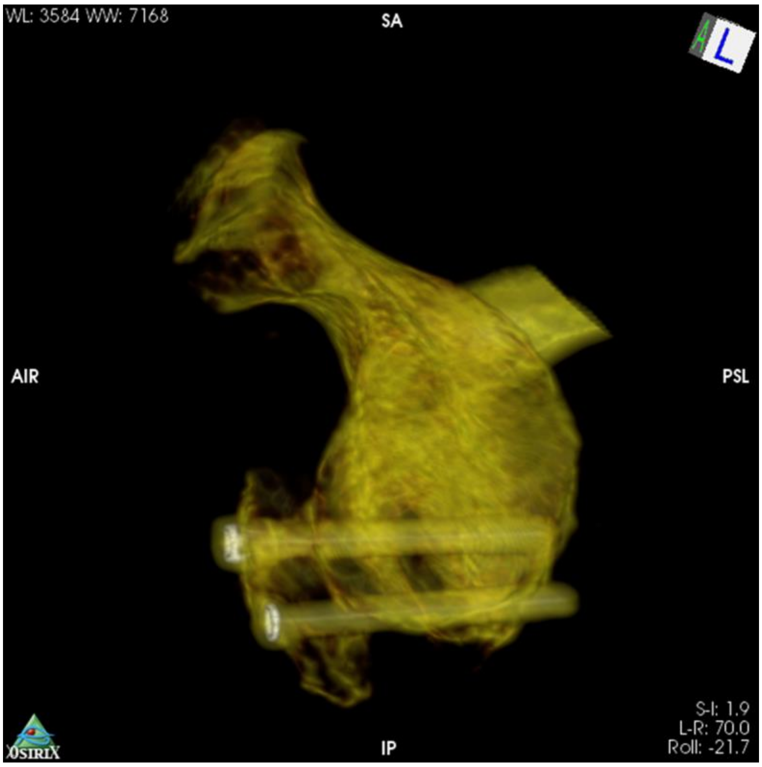

Figure 8. 3D reconstruction of the lower position of the CG in the specimen 17. Note that the inferior screw is barely fixed in the lower segment of the glenoid.

In the transverse plane, a significant tendency to place the superior screw closer to the medial border of the coracoid graft was observed in the AG. It seems that the tendency to medial placement of the screws, in our case the proximal screw, is a deliberate act on the part of the surgeon. Lafosse et al. recommend placing the guide discretely medial to avoid protrusion of the head of the screw in its final placement in the neck of the scapula and avoid problems in mobility and rotations of the humeral head.[27] This medial position of the screws increase the risk of a fracture when using a narrower band of the CG and transferring a rotating movement to the CG as the screws are tightened. In fact, Lafosse et al. recommend not being very energetic when tightening the screws because of the risk of fracture.[27] Probably, in young patients with a wider coracoid process, a reasonable variation of position in the longitudinal and / or transversal axis does not suppose too many complications. However, there is objective data indicating that bone mineral density of the coracoid decreases with age.[3] In these cases, the correct centering of the screws seems much more important to avoid the possibility of fracture of the CG or the absence of consolidation, as the screws cannot be tightened enough due to the risk of fracture. In our study, the significant tendency to place the superior screw more medial in addition to the age of the specimens used may be related to the appearance of fractures in the AG (30%).

The main limitation of the present study, as it usually happens in anatomical studies on cadavers, lies in the small number of specimens that were used. In addition, each operation was performed by a different surgeon. This may have introduced performance bias. Finally, generalizability is uncertain as the findings may be specific for the 2 surgeons performing the study.

In conclusion, the open Latarjet technique requires less surgical time to complete the procedure, presents a lower number of intraoperative complications, and allows a more adequate placement of the CG, a better centering of the screws and a subscapularis split closest to the ideal position. The reported benefits of the arthroscopic Latarjet technique seem less clear if we take into account the added surgery time and complications.

REFERENCES

1. Barth J, Boileau P, Brzoska R, et al. Latarjet procedure: Arthroscopy versus open. Grenoble: Congrès Annuel de la Société Francophone d'Arthroscopie, 2015.
2. Barth J, Neyton L, Métais P, et al. Is the two-dimensional computed tomography scan analysis reliable for coracoid graft positioning in Latarjet procedures? *J Shoulder Elbow Surg*. 2017;26(8):e237-e242.
3. Beranger JS, Maqdes A, Pujol N, Desmoineaux P, Beaufils P. Bone mineral density of the coracoid process decreases with age. *Knee Surg Sports Traumatol Arthrosc*. 2014;24(2):502-506.
4. Bhatia S, Frank RM, Ghodadra NS, et al. The outcomes and surgical techniques of the Latarjet procedure. *Arthroscopy*. 2014;30(2):227-235.
5. Boileau P, Bicknell RT, El Fegoun AB, Chuinard C. Arthroscopic Bristow procedure for anterior instability in shoulders with a stretched or deficient capsule: the «belt-and-suspenders» operative technique and preliminary results. *Arthroscopy*. 2007;23(6):593-601.
6. Boileau P, Gendre P, Baba M, et al. A guided surgical approach and novel fixation method for arthroscopic Latarjet. *J Shoulder Elbow Surg* 20;25(1):78-89.
7. Boileau P, Mercier N, Roussanne Y, Thelu CE, Old J. Arthroscopic Bankart–Bristow–Latarjet procedure: the development and early results of a safe and reproducible technique. *Arthroscopy*. 2010;26(11):1434–1450.
8. Boileau P, Thélu CE, Mercier N, et al. Arthroscopic Bristow-Latarjet combined with bankart repair restores shoulder stability in patients with glenoid bone loss. *Clin Orthop Relat Res*. 2014;472(8):2413–2424.

9. Burkhart SS, De Beer JF. Traumatic glenohumeral bone defects and their relationship to failure of arthroscopic Bankart repairs: Significance of the inverted-pear glenoid and the humeral engaging Hill-Sachs lesion. *Arthroscopy*. 2000;16(7):677-694.
10. Burkhart SS, De Beer JF, Barth JR, Criswell T, Roberts C, Richards DP. Results of modified Latarjet reconstruction in patients with anteroinferior instability and significant bone loss. *Arthroscopy*. 2007;23(10):1033-1041.
11. Casabianca L, Gerometta A, Massein A, et al. Graft position and fusion rate following arthroscopic Latarjet. *Knee Surg Sports Traumatol Arthrosc*. 2016;24(2):507-512.
12. Cassagnaud X, Maynou C, Mestdagh H. Clinical and computed tomography results of 106 Latarjet-Patte procedures at mean 7.5 year follow-up. *Rev Chir Orthop Reparatrice Appar Mot*. 2003;89(8):683–692.
13. Cunningham G, Benchouk S, Kherad O, Lädermann A. Comparison of arthroscopic and open Latarjet with a learning curve analysis. *Knee Surg Sports Traumatol Arthrosc*. 2016;24(2):540-545.
14. Gracitelli ME, Ferreira AA, Benegas E, Malavolta EA, Sunada EE, Assunção JH. Arthroscopic Latarjet procedure: safety evaluation in cadavers. *Acta Ortop Bras*. 2013;21(3):139-43.
15. Hinton MA, Parker AW, Drez D Jr, Altcheck D. An anatomic study of the subscapularis tendon and myotendinous junction. J Shoulder Elbow Surg. 1994;3(4):224-229.
16. Hovelius L, Sandström B, Olofsson A, Svensson O, Rahme H. The effect of capsular repair, bone block healing, and position on the results of the

Bristow-Latarjet procedure (study III): long-term follow-up in 319 shoulders. *J Shoulder Elb Surg*. 2012;21(5):647–660.

17. Hovelius L, Sandstrom B, Saebo M. One hundred eighteen Bristow-Latarjet repairs for recurrent anterior dislocation of the shoulder prospectively followed for fifteen years: study II—the evolution of dislocation arthropathy. *J Shoulder Elb Surg*. 2006;15(3):279–289.
18. Kany J, Flamand O, Grimberg J, et al. Arthroscopic Latarjet procedure: Is optimal positioning of the bone block and screws possible? A prospective computed tomography scan analysis. *J Shoulder Elbow Surg*. 2016;25(1):69-77.
19. Kordasiewicz B, Kicinski M, Małachowski K, Wieczorek J, Chaberek S, Pomianowski S. Comparative study of open and arthroscopic coracoid transfer for shoulder anterior instability (Latarjet)-computed tomography evaluation at a short term follow-up. Part II. *Int Orthop*. 2018;42(5):1119-1128.
20. Kraus TM, Graveleau N, Bohu Y, Pansard E, Klouche S, Hardy P. Coracoid graft positioning in the Latarjet procedure. *Knee Surg Sports Traumatol Arthrosc*. 2016;24(2):496-501.
21. Kraus TM, Martetschläger F, Graveleau N, et al. CT-based quantitative assessment of the surface size and en-face position of the coracoid block post-Latarjet procedure. *Arch Orthop Trauma Surg*. 2013;133(11):1543–1548.
22. Lädermann A, Denard PJ, Arrigoni P, Narbona P, Burkhart SS, Barth J. Level of the subscapularis split during arthroscopic Latarjet. *Arthroscopy*. 2017;33(12):2120-2124.

23. Lädermann A, Denard PJ, Burkhart SS. Injury of the suprascapular nerve during latarjet procedure: an anatomic study. *Arthroscopy*. 2012;28(3):316-21.
24. Lädermann A, Lubbeke A, Stern R, Cunningham G, Bellotti V, Gazielly DF. Risk factors for dislocation arthropathy after Latarjet procedure: a long-term study. *Int Orthop*. 2013;37(6):1093–1098.
25. Lafosse L, Boyle S. Arthroscopic Latarjet procedure. *J Shoulder Elbow Surg*. 2010;19(2 suppl):2-12.
26. Lafosse L, Boyle S, Gutierrez-Aramberri M, Shah A, Meller R. Arthroscopic Latarjet Procedure. *Orthop Clin North Am*. 2010;41(3):393-405.
27. Lafosse L, Lejeune E, Bouchard A, Kakuda C, Gobezie R, Kochhar T. The arthroscopic Latarjet procedure for the treatment of anterior shoulder instability. *Arthroscopy*. 2007;23(11):1242.e1-1242.e5.
28. Latarjet M. Treatment of recurrent dislocation of the shoulder. *Lyon Chir*. 1954;49(8):994-997.
29. Longo UG, Loppini M, Rizzello G, Ciuffreda M, Maffulli N, Denaro V. Latarjet, Bristow, and Eden-Hybinette procedures for anterior shoulder dislocation: systematic review and quantitative synthesis of the literature. *Arthroscopy*. 2014;30(9):1184–1211.
30. Lunn JV, Castellano-Rosa J, Walch G. Recurrent anterior dislocation after the Latarjet procedure: outcome after revision using a modified Eden-Hybinette operation. *J Shoulder Elb Surg*. 2008;17(5):744–750.
31. Marion B, Klouche S, Deranlot J, Bauer T, Nourissat G, Hardy P. A prospective comparative study of arthroscopic versus mini-open Latarjet

procedure with a minimum 2-year follow-up. *Arthroscopy*. 2017;33(2):269-277.

32. Neyton L, Barth J, Nourissat G, et al. Arthroscopic Latarjet techniques: Graft and fixation positioning assessed with 2-dimensional computed tomography is not equivalent with standard open technique. *Arthroscopy*. 2018;34(7):2032-2040.

33. Nourissat G, Delaroche C, Bouillet B, Doursounian L, Aim F. Optimization of bone-block positioning in the Bristow-Latarjet procedure: a biomechanical study. *Orthop Traumatol Surg Res*. 2014;100(5):509–513.

34. Patte D, Bernageau J, Bancel P. The anteroinferior vulnerable point of the glenoid rim. In: Bateman JE, Welsch RP, eds. Surgery of the shoulder, Marcel Dekker, New York; 1985:94–99.

35. Russo A, Grasso A, Arrighi A, Pistorio A, Molfetta L. Accuracy of coracoid bone graft placement: Open versus arthroscopic Latarjet. *Joints*. 2017;5(2):85-88.

36. Samim M, Small KM, Higgins LD. Coracoid graft union: a quantitative assessment by computed tomography in primary and revision Latarjet procedure. *J Shoulder Elbow Surg*. 2018;27(8):1475-1482.

37. Taverna E, Guarrella V, Cartolari R, et al. Arthroscopically-assisted Latarjet: an easy and reproducible technique for improving the accuracy of graft and screw placement. *Shoulder Elbow*. 2018;10(2):99-106.

38. Weel H, Tromp W, Krekel PR, Randelli P, van den Bekerom MP, van Deurzen DF. International survey and surgeon's preferences in diagnostic work-up towards treatment of anterior shoulder instability. *Arch Orthop Trauma Surg*. 2016;136(6):741-746.

39. Young AA, Maia R, Berhouet J, Walch G. Open Latarjet procedure for management of bone loss in anterior instability of the glenohumeral joint. *J Shoulder Elbow Surg*. 2011;20(2 suppl):S61-69.
40. Zhu Y, Jiang C, Song G. Arthroscopic versus open Latarjet in the treatment of recurrent anterior shoulder dislocation with marked glenoid bone loss. *Am J Sports Med*. 2017;45(7):1645-1653.