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Review article

Basic morphological characteristics of coracoid grafts obtained by open and arthroscopic Latarjet techniques: A comparative study

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ABSTRACT

Background: A knowledge of the anthropometric characteristics of the coracoid graft (CG) that can be obtained by the open and arthroscopic Latarjet techniques may be beneficial in the preoperative planning and intraoperative decision making for coracoid osteotomy and transfer. We have not found any study that compared the morphology of the CG that can be obtained from open and arthroscopic Latarjet techniques. The purpose of this study was to verify if the basic anthropometric characteristics of CGs are equivalent.
Hypothesis: We hypothesize that the basic anthropometric characteristics of the CGs are similar.
Methods: Twenty fresh-frozen human paired cadaveric shoulder specimens that had been randomly distributed in two groups of 10 specimens each were used. Two surgeons, each with experience in performing the open and arthroscopic Latarjet technique, performed these procedures in each of the respective groups (OG, open group; AG, arthroscopic group). A CT scan was performed. Using the volume rendering technique, a metric analysis of the volume, area and length of the CG were performed, evaluated and statistically analysed.
Results: There were no significant differences in length ($p = 0.162$) (mean length, 22.6 mm for OG and 23.6 mm for AG). There were significant differences in the volume ($p = 0.031$) and area ($p = 0.007$) of the CG, being lower in the OG (mean volume, 2.8 cm^3 for OG and 3.6 cm^3 for AG; mean area, 9.9 cm^2 for OG and 12.8 cm^2 for AG). No significant differences were observed by sex or laterality.
Conclusion: The mean lengths of the CGs that were obtained by each technique are equivalent. However, the areas and volumes of the grafts are different, being lower in the open surgery. These differences have not been an impediment to perform the technique. Our results corroborates that consolidation is more related to the preparation and placement than to the anthropometric characteristics of the CG. No significant differences were observed by sex or laterality.
Level of evidence: Basic Science.

1. Introduction

The Latarjet coracoid bone block stabilization method [1] is one of the reference procedures that is used for the treatment of recurrent anterior shoulder instability, particularly in patients with significant bone loss [2]. Perhaps the most important modification to this technique that has occurred in recent years has been its incorporation into a minimally invasive surgical technique [3,4]. The results of this technique are excellent, with a recurrence rate lower than 5% in most series [5,6] and with optimal functional results [7]. However, the complication rate is not negligible and ranges, according to the series, between 15 and 30% of cases, including patients with partial or complete neurological injury [8,9] and vascular injury [10]. In their meta-analysis, Griesser et al. reviewed 45 articles that had been published on the complications of open and arthroscopic Latarjet technique and determined that the need to obtain a coracoid graft (CG) that has an appropriate length for the placement the screws is associated with fracture in 1.5% of the cases [11]. The morphometry of the coracoid process has been a study area of interest for several researchers [12–20]. However, we have not found any study that compared the morphology of the CG that can be obtained from both techniques. A knowledge of the

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anthropometric characteristics of the CG that can be obtained by the open and arthroscopic Latarjet techniques may be beneficial in the preoperative planning and intraoperative decision making for coracoid osteotomy and transfer.

In a cadaveric study comparing CG fixation and position in open versus arthroscopic Latarjet techniques (under review), we consider verify if the basic anthropometric characteristics of CGs are equivalent. We hypothesize that are similar.

2. Materials and methods

The study was performed in accordance with the Declaration of Helsinki. Twenty fresh-frozen human paired cadaveric shoulders were used for this study. 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:

- the open surgical group (OG), labelled 1 to 10 (4 females and 6 males, 4 rights and 6 left), received the open surgical technique;
- the arthroscopic surgical group (AG), labelled 11 to 20 (4 females and 6 males, 6 rights and 4 left), received the arthroscopic surgical technique (Table 1).

All of the shoulders were placed in the "beach chair" position. To guarantee that the open and arthroscopic procedures were carried out in accordance with the standard technique, a surgeon with proven experience was chosen for each of them.

2.1. Open Latarjet technique

The open Latarjet technique was performed on the OG by the same surgeon, with modifications to the classical technique that was described by Patte et al. [21] 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).

A deltopectoral approach was used to access the coracoid process. Once the soft tissues are released, the coracoid osteotomy is performed with a 90° angled saw, cutting in bevel the entire horizontal portion and part of the anterior cortex of the vertical portion [21].

The procedure was completed following the classic description of the technique until closing.

2.2. Arthroscopic Latarjet technique

The arthroscopic Latarjet technique was performed on the AG by the same surgeon with modifications to the classical technique that was described by Lafosse et al. [3] 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 (De Puy Mitek, Wokingham, UK) were also used for the arthroscopic Latarjet.

An osteotomy of the coracoid process is performed proximal to the insertion of the coracoclavicular ligaments, thus obtaining a large CG [3]. The original osteotomy was mechanically performed with a sharp chisel which implied a high risk of impact fracture. At present, it is performed with a small size drill to cut the coracoid process or to weaken the cutting area.

The procedure was completed following the classic description of the technique until closing.

2.3. 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-). The shoulders were placed and centred on the table resting on their dorsal face and were fixed in neutral rotation. 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 the postprocessing steps, orthogonal reconstructions were performed 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 analyse 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.

The anthropometric characteristics of each CG were measured. Length was obtained by first selecting the CT cut in which the length of the CG was greater and by subsequently applying the length measuring tool of the radiographic analysis software. The results were computed in millimetres. Volume was obtained after the radiographic images corresponding to the CG were labelled in all of the sagittal sections with the application of the volumetric reconstruction software. The results that were obtained were computed in cubic centimetres (Figs. 1 and 2). Area was obtained in a similar manner as the volume after applying the specific software for measuring surfaces. The results that were obtained were computed in square centimetres (Figs. 1 and 2).

2.4. Statistical analysis

In each of the 3 measured anthropometric characteristics, two analyses of variance of two factors (technique, sex; technique, side) were performed. For the statistical analysis of the data, the IBM SPSS

Table 1
Epidemiology of the specimens selected for the study and their distribution in groups.

	Specimen	Sex	Side		Specimen	Sex	Side
OG	1	Female	Right	AG	11	Male	Right
	2	Female	Left		12	Female	Right
	3	Female	Right		13	Male	Right
	4	Male	Left		14	Male	Right
	5	Male	Left		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

AG: arthroscopic surgery group; OG: open surgery group.

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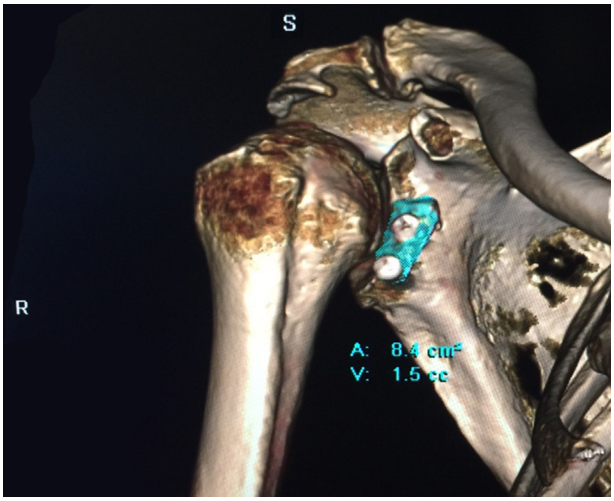

Fig. 1. Calculation of volume and total area by selecting the image of the coracoid process in the 3D reconstruction. The specimen is on the right side.

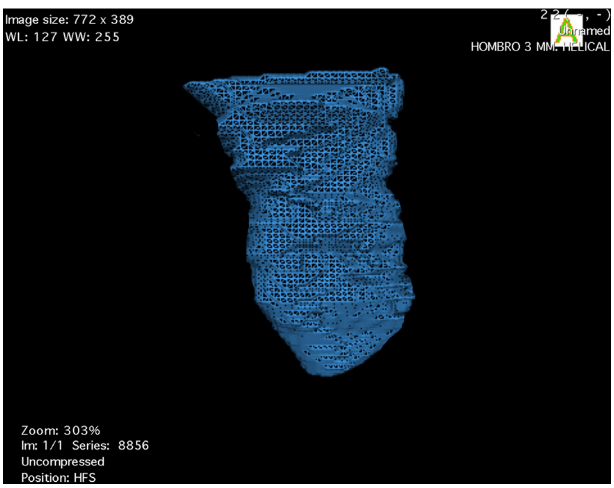

Fig. 2. Calculation of volume and total area by rendering the regions of interest in the coronal sections (the OsiriX™ computer program was used).

Table 2
Descriptive statistics. Dependent variable: coracoid graft length (mm).

Sex	Technique	Mean	Std. deviation	Nº
Male	Open	22,447	1369	6
	Arthroscopic	23,836	1485	5
	Total	23,078	1531	11
Female	Open	22,878	0.423	4
	Arthroscopic	23,360	1764	4
	Total	23,119	1215	8
Total	Open	22,619	1072	10
	Arthroscopic	23,624	1527	9
	Total	23,095	1370	19

Statistics Base 25.0 program was used, with statistical significance set at 95% ($p \leq 0.05$).

3. Results

The procedure was completed in 10 specimens of the OG and 9 of the AG. In the AG, one of the specimens suffered a longitudinal fracture in the coracoid process when the osteotomy was performed. That fracture rendered that specimen unusable for grafting.

The results of the statistical analyses of each parameter studied are shown in Tables 2–4 and Figs. 3–5.

Table 3
Descriptive statistics. Dependent variable: coracoid graft volume (cm^3).

Sex	Technique	Mean	Std. deviation	Nº
Male	Open	3291	0.514	6
	Arthroscopic	3774	1372	5
	Total	3510	0.974	11
Female	Open	2180	0.310	4
	Arthroscopic	3572	0.734	4
	Total	2876	0.909	8
Total	Open	2847	0.713	10
	Arthroscopic	3684	1074	9
	Total	3243	0.975	19

Table 4
Descriptive statistics. Dependent variable: coracoid graft area (cm^2).

Sex	Technique	Mean	Std. deviation	Nº
Male	Open	11,316	1043	6
	Arthroscopic	13,050	3655	5
	Total	12,104	2590	11
Female	Open	7880	0.410	4
	Arthroscopic	12,550	1981	4
	Total	10,215	2825	8
Total	Open	9942	1952	10
	Arthroscopic	12,827	2867	9
	Total	11,308	2784	19

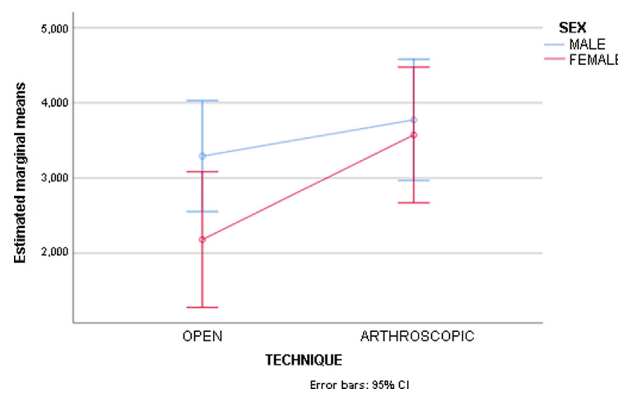

Fig. 3. Estimated marginal means of the coracoid graft length (mm).

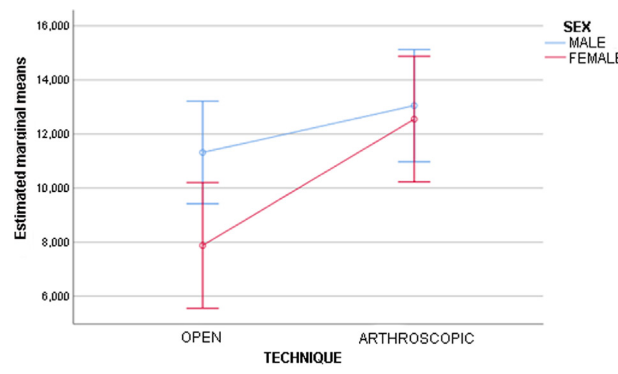

Fig. 4. Estimated marginal means of the coracoid graft volume (cm^3).

There were no significant differences in the mean length of the transferred CG ($p = 0.162$), which was 22.6 mm for the OG and 23.6 mm for the AG (Table 2 and Fig. 3). No significant differences were observed by sex ($p = 0.973$) or laterality ($p = 0.768$).

The mean volume of the CGs that were obtained by open surgery was significantly lower than that obtained with arthroscopic surgery ($p = 0.031$); the means volume were 2.8 cm^3 for

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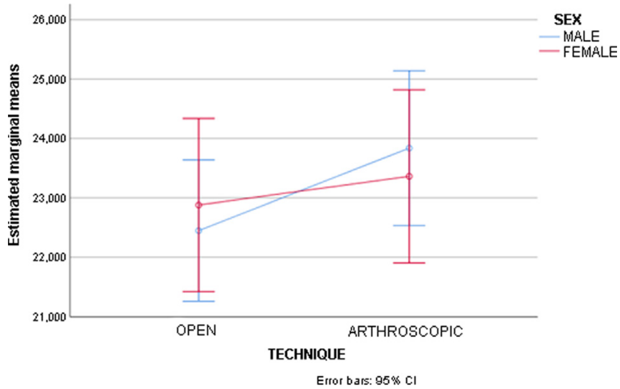

Fig. 5. Estimated marginal means of the coracoid graft area (cm^2).

the OG and 3.6 cm^3 for the AG. No significant differences were observed by sex ($p = 0.117$). Differences were observed in the OG, the volume of the CGs was lower in female (2180 ± 0.310) than in male (3291 ± 0.514). No significant differences were observed by laterality ($p = 0.331$) (Table 3 and Fig. 4).

The mean area of the CGs that were obtained by open surgery was also significantly lower than that obtained by arthroscopic surgery ($p = 0.007$); the means were 9.9 cm^2 for the OG and 12.8 cm^2 for the AG (Table 4 and Fig. 5). No significant differences were observed by sex ($p = 0.071$). Differences were observed in the OG, the area of the CGs was lower in female (7880 ± 0.410) than in male (11,316 ± 1043). No significant differences were observed by laterality ($p = 0.281$).

4. Discussion

In our results, there were no significant differences in length of the CGs that were obtained from the open versus arthroscopic Latarjet techniques. However, significant differences were found in the volume and area, being lower in the open surgery.

The morphological characteristics of the CG must be adequate to allow the placement of two screws. An important technical detail is the separation of the holes to fix the screws and the centring of these screws within the longitudinal and transverse axes of the transferred graft. Placing the screws too close together (less than 9 mm) could induce a longitudinal fracture and prevent an effective compression of the graft on the glenoid [22,23].

In the AG one of the specimens suffered a longitudinal fracture in the coracoid process when the osteotomy was performed. The advanced age of the specimens that we used in our study increased the need to follow the recommendation of Lafosse et al. [24] to not use too much energy when tightening the screws due to a potential risk of fracture. Furthermore, there are objective data that indicate that the bone mineral density of the coracoid decreases with age [25].

Several quantitative anatomical studies have been conducted on the length of the coracoid process. These studies measured the distance from the tip to the end of the horizontal portion of the coracoid. The majority of these studies have been performed on dry scapulae [13,17], on the shoulders of cadavers [14,15,18–20] or in living populations using CT scans [15,18,19]. These revised studies have estimated a mean length of the coracoid to be between 34.25 ± 1.28 and 46.3 ± 3.3 mm [12–20]. For the type of surgeries that we compared in the present study, these lengths are not of interest. We are interested in the maximum length of coracoid that can be transferred. That is defined as the distance from the coracoid tip to the anterior extent of the coracoclavicular ligaments. The coracoclavicular ligaments must be preserved to maintain the acromioclavicular stability. The measurements of coracoid that can be transferred obtained in other studies [3,14,18,19,26] coincide with those obtained in our study of 22.6 mm on average in the OG and 23.6 mm in the AG. From the CT scans of 34 shoulders, Armitage et al. measured the length of the coracoid along its undersurface from its tip to the elbow. They determined that the lengths of the coracoid that were available for transfer were only 16.8 ± 2.5 mm, which would hinder its fixation on the neck of the scapula [12].

Using 10 fresh-frozen human cadaveric shoulders (5 males and 5 females), Chahla et al. described the minimum distance between the coracoid apex and the trapezoid ligament to be 25.1 mm. They noted that the mean distance was different between males (28.1 mm) and females (22 mm) [27]. The minimum length that they observed coincides with those of our study. However, in our larger samples size, no significant differences were found between the male and female specimens.

Regarding the volume and the area of the CGs, there were no significant differences by sex or laterality. However, differences were observed in the OG, the volume and area was lower in female than in male.

The current literature does not provide a comprehensive report of the minimum length that the CG must have to be transferred and fixed with two screws, but the lengths that we obtained in our study from the two procedures are broad enough so that both techniques can be performed with confidence.

None of the reviewed works measured the volume and area of coracoids that can be transferred [12–20,27]. In the present study, the volume and area of the CGs that were obtained by arthroscopic surgery were significantly greater than those in the specimens that were obtained by open surgery. We believe that these significant differences are due to the different preparations of the CG for its implantation on the neck of the scapula. In open surgery, once the graft is obtained, the base of the coracoid process is treated with the angled saw, which eliminates a large amount of graft bone. This theoretically improves the consolidation rate but decreases the volume and area. In the arthroscopic surgery, the treatment with the angled saw is not performed, and instead irregularities in the graft are gently bevelled and smoothed with a chisel, thus preserving the larger volume and area. This method of preparation does not affect the length of the grafting coracoid. These differences have not been an impediment to perform the technique. Although the areas and volumes of the CGs are different, this does not result in differences to the clinical integrity or feasibility of the CGs. We can consider that the volume and the area of the coracoids that are obtained from both techniques are adequate to perform the graft.

Nonunion of the CG to the glenoid is a known complication of the Latarjet procedure. The rate of nonunion appears higher in the artrhoscopic surgery, 20% [28], than in arthroscopic surgery, 1.5% to 9.1% [11,29]. Hamel et al. [30] propose that poor vascularization of the CG could influence the high rate of nonunion observed, being related to the CG preparation.

In our cadaveric studio, the CG nonunion cannot be evaluated. However, that the volume and area are greater in arthroscopic surgery corroborates that consolidation is more related to the preparation and placement than to the anthropometric characteristics of the CG.

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 conclusion, the mean lengths of the CGs that were obtained from the open and arthroscopic Latarjet techniques are equivalent. However, the areas and volumes of the grafts are different, being lower in the open surgery. These differences have not been an impediment to perform the technique. Our results corroborates that consolidation is more related to the preparation and placement than to the anthropometric characteristics of the CG. No significant differences were observed by sex or laterality.

Disclosure of interest

The authors declare that they have no competing interest.

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Author contribution

A.M.A., F.G.E. and J.M.G. conception and design of the study and acquisition of data. A.M.A., F.G.E., J.R.M.V., C.B.A., C.C.B. and J.M.G. analysed and interpreted the data. A.M.A. and J.M.G. drafting the article and revising it critically for important intellectual content. A.M.A., F.G.E., J.R.M.V., C.B.A., C.C.B. and J.M.G. final approval of the version to be submitted.

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