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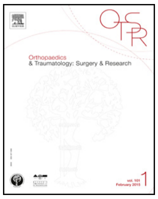

Original article

Arthroscopic congruent-arc shoulder bone-block for severe glenoid bone defect: Preliminary report

Q1 J. Kany[a,*], B. Codanda[b], P. Croutzet[a], R. Guinand[a]

[a] Clinique de l'Union, Shoulder, Boulevard de Ratalens, 31240 Saint-Jean, France
[b] Sakra World Hospital, Bangalore, India

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ABSTRACT

Introduction: Glenoid bone defect remains a surgical challenge in managing anterior shoulder instability. The technique first described by Latarjet has become the gold standard, but may fail to restore fully normal anatomy in case of severe "inverted-pear" glenoid bone defect. Likewise, the naturally "banana-shaped" coracoid process fails to match this flat shoulder. The congruent-arc modified Latarjet technique, which consists in pivoting the coracoid process through 90°, optimizes the contact surface, adapting to the glenoid curvature radius and increasing the articular surface of the graft.
Hypothesis: The present study hypothesis was that the congruent-arc bone-block technique could be performed entirely under arthroscopy. The main study objective was to assess the postoperative increase in glenoid surface area. The secondary objective was to assess whether the technique provided anatomic glenoid reconstruction.
Materials and methods: Five patients with inverted-pear glenoid were recruited in a preliminary prospective study. Immediate postoperative coracoid process length, width and thickness were measured on 2D CT scan and bone-block flushness was assessed using a straight-line and a circle. Glenoid surface area and coracoid graft area were also measured.
Results: Mean coracoid process length was 2.62 cm (range, 2.17–3.05 cm), width 1.52 cm (range, 1.28–1.75 cm) and thickness 1.16 cm (range, 0.9–1.3 cm). Mean preoperative glenoid area was 5.62 cm^2 (range, 4.76–6.31 cm^2) and the articular area of the coracoid process was 2.78 cm^2 (range, 2.43–3.27 cm^2). The coracoid graft thus increased glenoid area by a mean 49.2% (range, 41–53%). Axial CT slices systematically showed good bone-block positioning.
Discussion and conclusion: The congruent-arc technique can be performed entirely under arthroscopy, and provides anatomic glenoid reconstruction. It offers an option in case of severe inverted-pear glenoid bone defect.
Type of study: Prospective.
Level of evidence: III, case-control.

1. Introduction

Antero-inferior glenoid bone defect is frequently associated with recurrent anterior shoulder joint instability and is one of the main causes of failure of reconstruction surgery and capsule-ligament retensioning [1,2]. It is therefore essential for it to be diagnosed and treated by an appropriate bone reconstruction technique.

Among the various bone-block techniques published [3–7], the Latarjet technique [5] has become the gold-standard treatment for anterior shoulder instability associated with bone defect or HAGL lesion (Humeral Avulsion of the Gleno-humeral Ligament), or when the Bankart procedure fails. Its efficacy lies in a triple blocking effect [8]:

- coracoid transfer, increasing articular arc and thus preventing Hill-Sachs posterior humeral lesion;
- lowered inferior third of the subscapularis crossed by the conjoint tendon, creating a hammock effect, especially in external rotation in abduction (ER2);
- reattachment of the capsule to the coracoacromial ligament.

Lafosse showed the Latarjet procedure to be feasible under arthroscopy [9,10], without reinserting the coracoacromial

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[*] Corresponding author.
E-mail address: jean.kany@clinique-union.fr (J. Kany).

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ligament onto the capsule, thereby modifying the "triple locking" described by Patte [8].

In the classic Latarjet procedure, the inferior surface of the coracoid process is decorticated [5,6]. In case of massive glenoid bone defect, a large amount of bone has to be removed from the naturally banana-shaped coracoid process for it to match the flat anterior glenoid surface. This reduces coracoid size and may leave a graft that is insufficient to fill the glenoid defect.

Certain modifications have been described, and notably Burkhart's "congruent-arc" technique [11]. The inferior surface of the coracoid process adapts particularly well to the radius of the glenoid curvature. CT analysis showed that the radius of curvature of the inferior surface of the coracoid process matches the radius of curvature of the intact anterior glenoid joint edge [12,13]. Open congruent-arc procedures have shown reproducibly good results [14].

The present study hypothesis was that the congruent-arc bone-block technique is feasible entirely under arthroscopy. The main objective was to assess the postoperative increase in glenoid area, and the secondary objective was to assess whether the technique provided anatomic glenoid reconstruction, especially in case of severe glenoid defect, where the classic Latarjet procedure meets its limits.

2. Materials and methods

The inclusion criterion consisted in traumatic anterior shoulder instability with "inverted-pear" glenoid. Bone defect was assessed on preoperative multiplanar 2D CT shoulder reconstruction and Gerber index. The sole exclusion criterion was non-traumatic instability.

Patients were selected over a 2-month period from January to February 2016. Eighteen patients were recruited: 5 operated on by the arthroscopic congruent-arc technique in a prospective study performed by a single shoulder surgeon (J.K.), and 13 with Gerber index < 80% receiving a classic arthroscopic Latarjet procedure. For 4 patients, this was their first surgery; the 5th had undergone failed bipolar locking for recurrent instability [15]. Mean ISIS score was 8 (SD, 1.22; range, 7–10).

The steps of this all-arthroscopic procedure were initially tried out on cadaver parts to assess the feasibility of the technique and instrumentation (DePuy Mitek, Raynham, MA, USA). After signing their informed consent, the patients were scheduled for surgery.

3. Surgical technique

The patient was placed in the beach-chair position, with shoulder and arm draped free. Surgery was performed under general anesthesia and interscalene block, with systolic blood pressure kept to a maximum 100 mmHg. A modified Lafosse technique [9,10] was used, comprising 3 steps.

3.1. Step 1: coracoid exposure and subscapularis split

Standard soft-point posterior and anterolateral portals were used to confirm glenoid bone loss and screen for other lesions such as HAGL, Hill-Sachs, SLAP or rotator-cuff tear. A shaver (DePuy Mitek, Raynham, MA, USA) was introduced in the anterolateral portal to open and debride the rotator interval down to the inferior surface of the coracoid, conjoint tendon and coracoacromial ligament. The coracoacromial ligament was released from the lateral aspect of the coracoid. The conjoint tendon was spared. The subscapularis joint surface capsule was also gently debrided, to prevent soft-tissue interposition during coracoid transfer, which could lead to non-union of the bone-block.

The flat antero-inferior glenoid aspect was freshened, using a long shaver burr (4.5 mm, Smith & Nephew Inc., Memphis, TN, USA), to achieve a perfectly flat surface. Any "bony-Bankart" lesion was excised. A horizontal split was made in the subscapularis next to the bone lesion, 1 cm below the superior edge of the subscapularis tendon. A new outside-in anterior portal was then performed under arthroscopic control, lateral to the conjoint tendon.

The arthroscope was then withdrawn via the posterior portal, and introduced in the anterolateral portal. A long blunt trocar was introduced via the posterior portal through the subscapularis split, parallel to the glenoid surface.

3.2. Step 2: coracoid osteotomy and instrumentation

The anterolateral portal was then used as viewing portal and the antero-inferior portal as working portal. The fatty landmark was identified, to distinguish the conjoint tendon from the pectoralis minor, which was released from the medial aspect of the coracoid process.

A complementary superior portal was created halfway between the coracoid tip and knee, plus a medial "east" portal [16]. Coracoid debridement was completed using the superior portal. Circumferential decortication was performed at the coracoid knee, using a 4.5 mm burr (Smith & Nephew Inc., Memphis, TN, USA), to prepare the osteotomy. The coracoid drill guide (DePuy Mitek, Raynham, MA, USA) was passed through the anterolateral portal to the lateral surface of the coracoid process. Two K-wires were passed outside-in through the guide (Fig. 1a). A 3.2 mm bit was used to drill 2 holes above the 2 guide-wires, at an interval of 8 mm. The brachial plexus was protected throughout this step by a smooth interposition device passed through the east portal (Fig. 1b). "Top Hat" washers (DePuy Mitek, Raynham, MA, USA) were not used.

Coracoid osteotomy was then performed at the junction between the horizontal and vertical limbs of the coracoid, using a curved osteotome.

3.3. Step 3: graft positioning and stabilization

A dedicated "Arthro-Latarjet" cannulated guide (DePuy Mitek, Raynham, MA, USA) was passed through the east portal and locked into the tunnels, enabling the coracoid process to be moved with precision. The coracoid graft was rotated through 90° to bring the medial surface, which was carefully decorticated, facing the glenoid. The trocar which had been passed through the subscapularis split was used to retract the inferior part downward, and a second trocar, brought forward through the antero-inferior portal was used to raise the superior fibers, thereby creating enough space for the coracoid graft to be introduced via the subscapularis split. At this point in the procedure, it was essential to locate the axillary nerve, to avoid any impingement or lesion.

The bone graft was then positioned on the anterior aspect of the glenoid in such a way that the guide-wire and posterior trocar were parallel. The medial surface of the graft was thus facing the anterior surface of the glenoid. Precise visual control was needed to ensure that graft positioning was neither too medial nor too lateral. Two guide-wires were then introduced through the cannulated guide, to cross the posterior aspect of the glenoid and the skin. After drilling with a cannulated 3.2 mm bit, two 3.5 mm cannulated screws stabilized the coracoid graft on the glenoid by compression. Graft positioning was checked via the posterior viewing portal (Fig. 1c). Shoulder stability in passive external rotation (ER1 and ER2) was checked intraoperatively.

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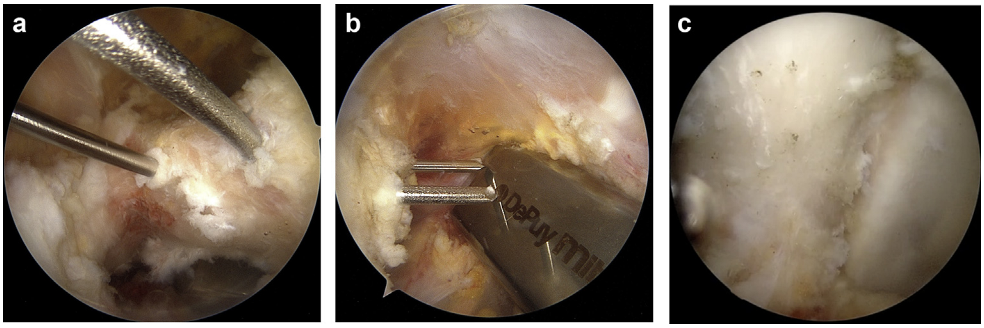

Fig. 1. Arthroscopic view: a: lateral view of coracoid process with k-wires penetrating the lateral aspect; b: medial coracoid aspect. Device protecting brachial plexus (right, behind tool) from K-wire tips; c: congruent-arc bone-block in position.

4. Postoperative rehabilitation

Patients wore a sling-and-swathe immobilizer for 4 weeks, and were encouraged to begin active and passive mobilization. Return to non-manual work was allowed on resolution of pain. Non-traumatic sports could be resumed after 3 months and contact or overhead sports after 6 months.

5. Postoperative X-ray and CT

Immediate postoperative plain AP X-ray and CT scan with multiplanar 2D reconstruction were taken. Osirix software (Pixmeo, Geneva, Switzerland) was used for measurement of coracoid length, width and thickness (Fig. 2a and b). Glenoid bone defect was assessed on Gerber index [17] (Fig. 2b). Bone-block position was checked by straight-line and circle assessment on oblique axial and sagittal slices [18] (Fig. 2c). The angle between a line through the anterior and posterior edges of the glenoid and the axis of the superior screw was measured. Area 1 was measured as native glenoid area (without bone defect) and area 2 as defect area; and area 3 (real glenoid area with defect) was calculated as A3 = A1 – A2. Coracoid graft area was also measured (A4) (Fig. 2d and e) and the A4:A3 ratio, representing the percentage increase in glenoid area by the congruent-arc graft, and A3:A1 ratio, representing the percentage preoperative loss of substance, were calculated and compared, to determine whether the congruent-arc bone-block adequately filled the initial defect.

CT images were also used to screen for intra-articular screw penetration or extra-osseous protrusion.

6. Statistics

Means, ranges and standard deviations were calculated. Statis 5.6.5 software was used to determine standard deviations. For this preliminary study of 5 patients, no correlations were analyzed.

7. Results

Results are shown in Table 1.

7.1. CT results

Mean Gerber index was 83.2% (SD, 2.59; range, 80–87%) and mean bone defect 26.8% (SD, 1.3; range, 25–28%), confirming the inverse-pear glenoid shape. On axial slices, the mean angle between the superior screw and glenoid surface was 4.6° (SD, 7.06°; range, 0–16°). Mean coracoid length was 2.62 cm (SD, 0.37; range, 2.17–3.05 cm); width, 1.52 cm (SD, 0.19; range, 1.28–1.75 cm); and thickness 1.16 cm (SD, 0.16; range, 0.9–1.3 cm). A1 (native glenoid area) was 7.68 cm^2 (SD, 0.8; range, 6.66-8.66 cm^2); A2 (glenoid bone defect), 2.06 cm^2 (SD, 0.24; range, 1.76–2.35 cm^2); A3 (real glenoid area with defect), 5.62 cm^2 (SD, 0.59; range, 4.76–6.31); and A4 (congruent-arc coracoid graft area), 2.78 cm^2 (SD, 0.38; range, 2.43–3.27 cm^2). The congruent-arc coracoid graft increased glenoid area by a mean 49.2% (SD, 4.97; range, 41–53%). Axial slices showed bone-block protrusion of 0.16 cm (SD, 0.1; range, 0–0,24 cm) on straight-line assessment and 0.07 cm (SD, 0.11; range 0–0.25 cm) on circle assessment: i.e., all bone-blocks were flush. Finally, oblique sagittal slices showed correct bone-block positioning at the glenoid defect in all cases.

7.2. Immediate complications

There were no vascular lesions or neurologic complications. There were no coracoid fractures and no cross-overs to open surgery. There were no cases of intra-articular screw penetration or posterior protrusion exceeding 5 mm.

8. Discussion

“Inverted-pear” glenoid, in which superior diameter is greater than inferior diameter, results from a bone defect exceeding 25% of joint surface area [19,20].

We considered the possibility that the bone graft, as described by Latarjet [5], might sometimes be too small to restore natural glenoid anatomy when the bone defect is very large. There is indeed a considerable morphological difference in curvature radius between the inferior aspect of the coracoid process and the anterior edge of the pathological glenoid. This is why the inferior surface of the coracoid needs not only to be decorticated but also adapted and remodeled, using a long bur, to ensure congruency with the anterior aspect of the glenoid, enabling bone fusion [5,6,14,21]. In such cases, a large amount of substance has to be removed from the coracoid, which is naturally banana-shaped, to fit the flat anterior glenoid. Coracoid bone stock is consequently diminished, which may leave a graft too small to repair the actual glenoid defect. Moreover, with this smaller and therefore more fragile graft, the risk of fracture and/or proximal osteolysis is increased. In the congruent-arc technique, it is not necessary to resect a large amount of coracoid bone, as the graft naturally adapts to the flat “inverted-pear” glenoid. Only the anatomically flat medial surface of the coracoid process is decorticated to ensure fusion. The technique thus conserves graft bone stock, and this is one of its main advantages. Ghodadra [22] reported better restoration of the glenoid defect with the coracoid process oriented according to the congruent-arc concept, in which width is greater than thickness; the congruent-arc modification also improved head/glenoid contact pressure. Rajan showed that coracoid width was significantly greater (mean, 13.77 mm; range, 9.60–18.04 mm) than thickness (7.83 mm; range, 5.61–10.79 mm) [23], in agreement with the

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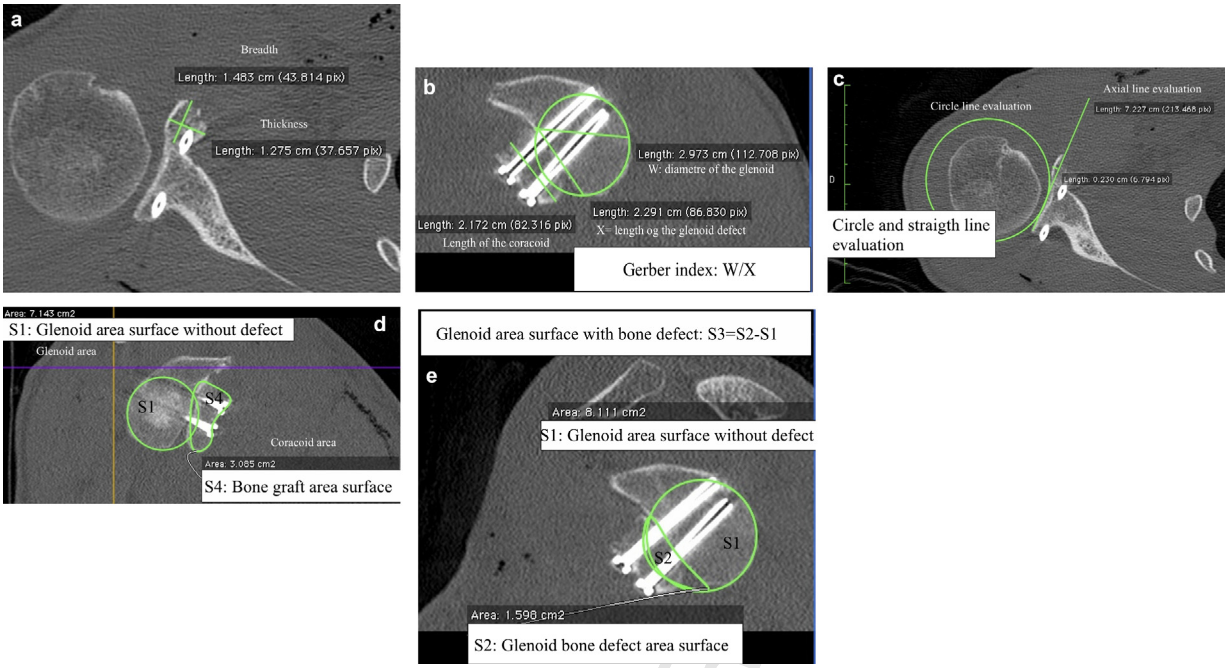

Fig. 2. CT assessment: a: graft thickness and width; b: Gerber index (W/X) and graft length; c: line and circle assessment of graft positioning on glenoid; d: glenoid area 1 (without defect), and area 4 (graft area); e: area 1 and defect area (area 2); area 3: glenoid area before graft: A3 = A1 – A2.

Table 1
Data.

	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Average
ISIS score	7	8	10	7	8	8
W (cm)	1.65	2.20	2.10	2.35	2.23	2.11 ± 0.27
X (cm)	2.01	2.65	2.65	2.7	2.65	2.53 ± 0.29
Gerber index W/X (%)	82	83	80	87	84%	83.2 ± 2.59
Screw length (cm)	3.2	3.6	4.0	3.8	3.8	3.68 ± 3.03
Overstuffing axial line (cm)	0.22	+0.2	+0.24	+0.15	0	0.16 ± 0.1
Overstuffing with circle line (cm)	0	–0.2	0	0	+0.1	–0.1
Screw/glenoid surface angle (°)	0	0	0	7	16	4.6 ± 7.06
Coracoid length (cm)	2.60	2.37	2.17	3.05	2.92	2.62 ± 0.37
Coracoid breadth (cm)	1.28	1.68	1.48	1.75	1.43	1.52 ± 0.19
Coracoid thickness (cm)	0.90	1.17	1.27	1.3	1.15	1.16 ± 0.16
A1 (cm^2)	6.66	8.11	7.86	8.66	7.11	7.68 ± 0.8
A2 (cm^2)	1.9	2.25	2.05	2.35	1.76	2.06 ± 0.24
A3 = A1 – A2 (cm^2)	4.76	5.86	5.81	6.31	5.35	5.62 ± 0.59
A4 (cm^2)	2.50	2.43	3.08	3.27	2.6	2.78 ± 0.38
A4/A3 (%)	52	41	53	52	48	49.2 ± 4.97
A3/A1 (%)	72	72	74	73	75	73.2 ± 1.3
Glenoid bone loss (%)	28	28	26	27	25	26.8 ± 1.3

W: length of the glenoid defect; X: diameter of the glenoid; A1: native glenoid surface area without bony defect; A2: glenoid bone defect surface area; A3: glenoid surface area with the bony defect; A3 = A2 – A1; A4: bone graft (congruent-arc coracoid) surface area that increases the glenoid surface A2; A4/A3 represents the glenoid surface area augmented by the congruent-arc coracoid; A3/A1 represents the residual glenoid bone stock.

present findings. Other authors [12,22–25] reached the same conclusions. This particular coracoid process anatomy thus enabled the congruent-arc graft to increase glenoid surface area by 49.2% in the present series; the technique could thus become the option of choice in inverted-pear glenoid.

Another advantage of the congruent-arc is that the curvature radius of inferior surface of the coracoid process is close to that of the anterior part of an intact glenoid [12]; this indeed was Burkhart's initial finding [11]. An in vitro study by Boons [13] showed that both the classic Latarjet procedure and the congruent-arc modification restored shoulder stability and ranges of motion, but that the congruent-arc provided greater forward translation of the humeral head, without greater risk of recurrent instability. De Beer, using the congruent-arc technique, was able to optimize contact force and graft curvature radius [14].

The present all-arthroscopic congruent-arc technique enabled precise bone-block positioning (Fig. 3a–c) and restored an anatomic joint surface.

It may be objected that the risk of musculocutaneous nerve lesion is increased by rotating the coracoid process through 90°. However, neurologic lesions (axillary, musculocutaneous and suprascapularis nerves) were reported in 10% of open Bristow-Latarjet procedures [26–29], which involved no coracoid rotation, whereas the present series showed none.

A second drawback could be a risk of impingement in external rotation between the subscapularis tendon and the bone-block, the latter being larger than in the classical Latarjet procedure. However no such impingement has been reported for the Bristow technique, in which the bone-block is positioned upright for at least 1 cm [6,16].

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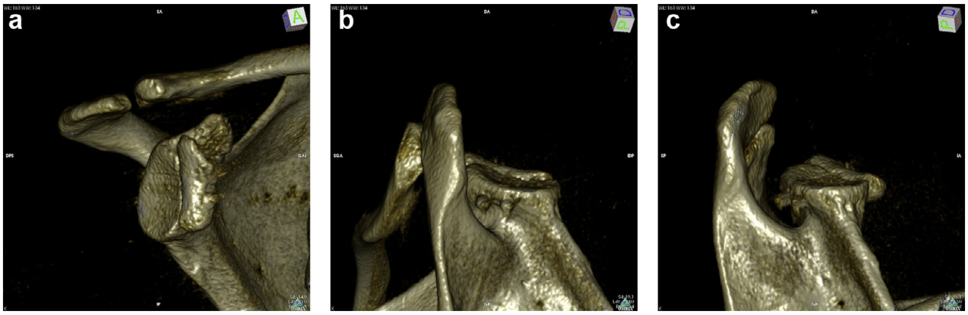

Fig. 3. a–c: postoperative 3D CT reconstruction. Anatomic glenoid restored by congruent-arc bone-block, even if the block is slightly too high.

A final drawback could be the thin coracoid process, with non-negligible risk of fracture during tunnel drilling. This, however, did not arise in the present 5 cases: the graft was fixed with two screws (DePuy Mitek, Raynham, MA, USA) without Top Hats which would have required 4.2 mm tunnels, with consequently greater fracture risk than with the present 3.2 mm tunnels [23].

Finally, Giacomo [30,31] reported greater coracoid bone-block osteolysis in cases without glenoid bone defect. Thus the correct indication for the congruent-arc technique would seem to be significant glenoid bone defect with Gerber index > 80%, in cases at low risk of subscapularis impingement and in which the classical Latarjet procedure would fail to restore the missing glenoid area. Conversely, as shown by Young, the classical Latarjet procedure may be indicated in cases of less severe glenoid defect, where the coracoid process is banana-shaped and long enough to match the convex anterior glenoid aspect [25].

The limitations of the present study lay in the small sample and lack of clinical follow-up. The objective was to demonstrate an alternative to the arthroscopic Eden-Hybbinette procedure [3,4], which allows a larger bone graft than the classical Latarjet technique in case of severe defect, but without hammock effect and with two drawbacks:

- need for a second harvesting site;
- elevated risk of osteolysis, as the graft is non-vascularized.

The present study is a preliminary report: consolidation was not assessed, which represents a further limitation. Although the congruent-arc technique optimizes contact force and bone-block curvature radius with respect to the glenoid, the contact area is still smaller than in the classical Latarjet procedure, which may lead to non-union.

More patients and longer follow-up will be required to assess results on this particularly anatomic technique and to screen for impingement between the subscapularis muscle and the screws.

9. Conclusion

Congruent-arc bone-block may be performed on an all-arthroscopic procedure, and significantly increases glenoid area. It constitutes an option in case of severe anterior glenoid defect, where the classical Latarjet technique runs up against limitations. The coracoid bone-block can be positioned with precision and stabilized on the antero-inferior side of the glenoid under arthroscopic control. Good knowledge of anatomy, adapted instrumentation and preliminary cadaver trials are prerequisites. This is a preliminary report, and follow-up will be needed to assess results over the long term.

Disclosure of interest

Jean Kany is a Mitek company consultant.

Régis Guinand and Pierre Croutzet declare that they have no competing interest.

B. Codanda has not supplied his declaration of competing interest. Q2

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