



# Traditional versus congruent-arc Latarjet anatomic and biomechanical perspective

Luciano A. Rossi  
Ignacio Tanoira  
Franco Luis De Cicco  
Maximiliano Ranalletta

- The congruent-arc Latarjet (CAL) allows reconstruction of a greater percentage of glenoid bone deficit because the inferior surface of the coracoid is wider than the lateral edge of the coracoid used with the traditional Latarjet (TL).
- Biomechanical studies have shown higher initial fixation strength between the graft and the glenoid with the TL.
- In the TL, the undersurface of the coracoid, which is wider than the medial edge used with the CAL, remains in contact with the anterior edge of the glenoid, increasing the contact surface between both bones and thus facilitating bone consolidation.
- The shorter bone distance around the screw with the CAL is potentially less tolerant of screw-positioning error compared to the TL. Moreover, the wall of the screw tunnel is potentially more likely to fracture with the CAL due to the minimal space between the screw and the graft wall.
- CAL may be very difficult to perform in patients with very small coracoids such as small women or skeletally immature patients.
- Radius of curvature of the inferior face of the coracoid graft (used with the CAL) is similar to that of the native glenoid. This may potentially decrease contact pressure across the glenohumeral joint, avoiding degenerative changes in the long term.

**Keywords:** anatomical; biomechanical; congruent arc; glenohumeral instability; Latarjet; traditional

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## Introduction

Among the techniques available for glenoid reconstruction in patients with glenoid bone deficiency, the most widely used is the Latarjet procedure.<sup>1,2</sup> This technique, described in 1954 by Michael Latarjet, consists of glenoid

reconstruction using the ipsilateral coracoid process as a graft.<sup>3</sup> The Latarjet procedure restores and extends the glenoid articular arc, whereas the conjoint tendon acts as a dynamic sling when the arm is abducted and externally rotated.<sup>4</sup> Additionally, a third procedure has been proposed to restore stability, consisting of repairing the capsulolabral complex.<sup>4</sup>

The traditional Latarjet (TL) surgery has proved to be effective for the management of recurrent anterior glenohumeral instability with glenoid bone deficiency.<sup>2,5-8</sup> However, it is not exempt from complications. A recent systematic literature review evaluated 13 studies with a minimum follow up of 10 years in patients who underwent the TL surgery.<sup>6</sup> The authors reported a recurrence rate of 8.5% and a revision rate of 3.7%. In addition, 38% of the patients exhibited arthritic changes and 35% had residual pain.<sup>6</sup> In an effort to maximize the reconstruction of the articular geometry of the glenoid and improve the results, Burkhart et al introduced some modifications to the TL surgery.<sup>9</sup> They thus described what they refer to as 'congruent-arc Latarjet' (CAL). In this technique, after performing osteotomy of the coracoid process distal to the coracoclavicular ligaments, the graft is rotated 90° so that the concave inferior surface of the coracoid process is aligned with the glenoid fossa and the medial border is in contact with the anterior surface of the glenoid.<sup>9</sup>

The CAL technique allows, in theory, a larger graft to be used since it uses the wider, inferior surface of the coracoid process for the reconstruction. As a result, it would be possible to reconstruct larger bone defects as well as provide a more significant bone-blocking effect. Moreover, due to its concave shape, the inferior surface of the coracoid process would better adapt to the concavity of the glenoid fossa and the convexity of the humeral head, thus reducing contact pressure and preventing joint degeneration.<sup>10-12</sup> There are some disadvantages of the CAL technique compared to the TL, though. First,

**Table 1. Advantages and disadvantages of each technique**

Variable		Background
Glenoid bone reconstruction	CAL allows reconstruction of a greater percentage of glenoid bone deficit. <sup>11,13,15</sup>	The inferior surface of the coracoid is wider than the lateral edge of the coracoid used with the TL. <sup>11,13,15</sup>
Initial fixation strength and stability	Higher initial fixation strength between the graft and the glenoid with the TL. <sup>12,20</sup>	CAL resulted in a significantly lower mean failure load compared with the TL. <sup>12,20</sup> Significantly greater graft displacement under load with the CAL compared with the TL. <sup>12,20</sup>
Bone consolidation	Greater potential for bone consolidation with the TL. <sup>11,13,15</sup>	In the TL the undersurface of the coracoid which is wider than the medial edge used with the CAL, remains in contact with the anterior edge of the glenoid, increasing the contact surface between both bones and thus facilitating bone consolidation. <sup>11,13,15</sup>
Graft lysis and resorption	<i>Controversial:</i> CAL potentially has advantages in terms of stability, since by reconstructing the glenoid beyond its original size, it would provide a greater bone-blocking effect, increasing stability. <sup>9,11,13,15</sup>	Long-term follow-up studies demonstrated that the bone graft is remodelled over time and that the glenoid cavity returns to its original size. <sup>33</sup>
Technical complexity and possible associated early complications	CAL is more technically demanding. <sup>10</sup>	The shorter bone distance around the screw with the CAL is potentially less tolerant of screw-positioning error compared to the TL. <sup>10</sup> CAL may be very difficult to perform in patients with very small coracoids such as small women or skeletally immature patients. The wall of the screw tunnel is potentially more likely to fracture with the CAL due to the minimal space between the screw and the graft wall. <sup>10</sup>
Risk of future arthropathy.	CAL associated with an increased risk of graft fragmentation. <sup>10</sup> Radius of curvature of the inferior face of the coracoid graft (used with the CAL) is similar to that of the native glenoid. <sup>11,20</sup>	Decreased contact pressure across the glenohumeral joint. <sup>11,20</sup>

Note. CAL, congruent-arc Latarjet; TL, traditional Latarjet.

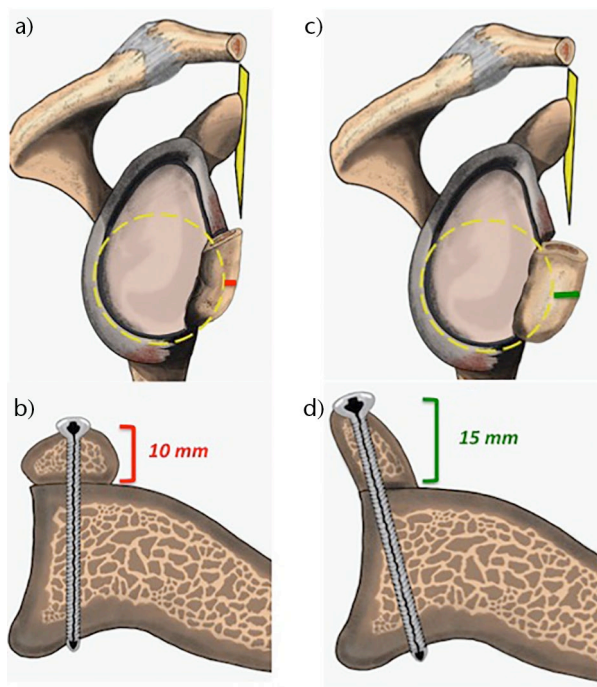
the bone contact area between the graft and the glenoid would be smaller because the narrower medial border would be the one in contact with the anteroinferior surface of the glenoid, which could in theory decrease the chances of bone consolidation.<sup>13,14</sup> Second, the CAL technique allows for a smaller space between the screws and the lateral and medial wall of the graft.<sup>10,13</sup> Consequently, two setbacks arise: first, high precision is required from the surgeon when placing the screws, thus complicating the surgical procedure.<sup>10,13</sup> Second, there is an increased risk of graft fragmentation as a result of leaving only 2 or 3 mm on each side of the hole made for the fixation screws.<sup>10,13</sup>

Unfortunately, despite being a widely used procedure, there is a lack of clinical comparative studies between the traditional and congruent-arc techniques. However, in the last decade numerous biomechanical and anatomical studies have come out with valuable information that could help the shoulder surgeon to choose the best option for their patients. The purpose of this review was to perform a comprehensive analysis of anatomical and biomechanical studies comparing the traditional and the congruent-arc Latarjet procedures with special emphasis on those that have been published in the last 10 years. Specifically, we evaluated: (a) glenoid bone reconstruction, (b) initial fixation strength and stability, (c) bone consolidation, (d) graft lysis and resorption, (e) technical complexity and possible associated early complications, (f) risk of future arthropathy.

## Glenoid bone reconstruction

With the CAL, the inferior surface of the coracoid is used, which, according to anatomical studies, measures an average of 15 mm (SD  $\pm$  2.2 mm) and is wider than the lateral edge of the coracoid used with the TL that measures on average 10.5 mm (SD  $\pm$  1.7 mm) (Table 1 and Fig. 1).<sup>13</sup> Therefore, defenders of the CAL technique argue that this variant is preferable since it allows reconstruction of a greater percentage of glenoid bone deficit.

In a recent cadaveric study, Bhatia et al<sup>15</sup> compared the ability to correct bone defects of different sizes with the TL and the CAL procedures. The authors simulated anterior defects by creating glenoid osteotomies (10%, 20%, 30%, and 40%). The authors found that in defects of up to 30%, both techniques similarly reconstructed the glenoid surface. However, in defects > 30%, the CAL reconstituted the glenoid cavity significantly better than the TL. These biomechanical advantages of the CAL for defects > 30% have also been described by other authors. Armitage et al<sup>13</sup> compared the total bone surface restored with the TL and that restored with the CAL in 34 computed-tomography-based three-dimensional models of the shoulder.<sup>13</sup> A tomographic model was used to simulate 20%, 35% and 50% anteroposterior glenoid defects in order to compare the two techniques in terms of their ability to reconstruct the defect. The authors reported that when the coracoid transfer was oriented in the congruent-arc manner, a significantly greater bone loss deficit was reconstructed.



**Fig. 1** Glenoid bone reconstruction. (A) Sagittal and (B) coronal images of the traditional Latarjet (TL). With this technique it is possible to reconstruct 10 mm of glenoid bone loss (red lines). (C) Sagittal and (D) coronal images of the congruent-arc Latarjet. With this technique it is possible to reconstruct 15 mm of glenoid bone loss (green lines).

On average, a 53% anterior glenoid bone loss scenario was reconstituted when using a congruent-arc orientation of the coracoid. In contrast, when the classic orientation of the coracoid was used, a reconstitution of 36% of the glenoid defect was obtained, on average ( $P < .001$ ). Finally, Ghodadra et al,<sup>11</sup> in a cadaveric study compared the amount of glenoid bone reconstruction in specimens with a 30% glenoid bone defect treated with the two coracoid graft orientations.<sup>11</sup> It was found that when the TL technique was used for reconstruction, restoration of the glenoid articular contact surface went from the 30% defect state to a 5% defect state. In contrast, complete restoration to the intact glenoid articular surface area was achieved through augmentation of the same defect size with the CAL technique.<sup>11</sup> However, it is important to note that glenoid bone defects  $> 35\%$  are not frequent in the clinical setting.<sup>16–18</sup> Therefore, although in the presence of a severe glenoid defect ( $> 35\%$ ) the congruent-arc variant might be preferable, it is possible that for most of the commonly treated glenoid defects, the classic technique would be enough to restore the glenoid to its original size. This was demonstrated by Paladini et al, who evaluated 23 patients operated with the TL procedure with a mean glenoid bone loss of 26% of the glenoid

surface (range 20–34%). In their study, the graft successfully restored the glenoid surface in all patients.<sup>19</sup>

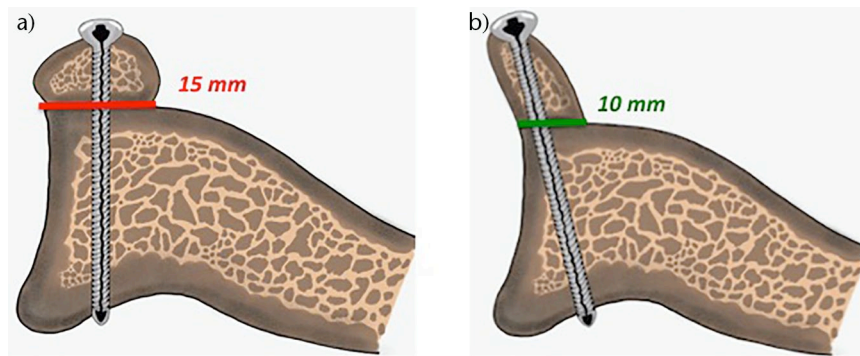
Finally, it is important to highlight that the restoration of glenoid bone deficiency is not the only stabilizing mechanism provided by the Latarjet surgery. The conjoint tendon, which remains inserted in the graft with both techniques, has also been shown to function as a stabilizing mechanism, especially when the shoulder is abducted and externally rotated. Yamamoto et al<sup>4</sup> in a biomechanical study in eight cadavers operated with classic Latarjet surgery, evaluated the stability provided by the ‘cinch effect’ of the conjoint tendon and that provided by the coracoid ‘bone-blocking effect’ at different levels of the range of motion. The authors reported that in the mid range and in the final range of motion, the conjoint tendon provided the highest percentage of the total glenohumeral stability, being the same 62% and 77% respectively.<sup>4</sup>

### Initial fixation strength and stability

Montgomery et al<sup>12</sup> compared the biomechanical fixation strength between the two Latarjet procedures. For this, they randomized 20 pairs of cadaveric shoulders to receive the TL or CAL technique. The authors utilized a model where a tensile force was applied through the conjoined tendon to replicate forces experienced by the coracoid graft in the early postoperative period, and the failure load was determined for each specimen. The CAL resulted in a significantly lower mean failure load ( $239 \pm 91$  N) compared with the TL ( $303 \pm 114$  N) ( $P = .005$ ) (Table 1).

Giles et al<sup>20</sup> conducted a similar cadaveric study comparing the two techniques in terms of fixation stability, strength and glenoid vault load transfer. A 25% anterior bone defect was created on 16 shoulder specimens (eight pairs), which were randomly assigned to either the TL or the CAL technique. Then, the specimens were tested by loading the glenohumeral joint while keeping the glenoid intact. It was observed that the application of a 30° anterior loading greater than 100 Newtons resulted in a significantly greater graft displacement in the CAL group when compared to the TL group (mean displacement range, 0.9–2.6 mm vs. 0.1–0.5 mm, respectively) ( $P < 0.004$ ). In addition, failure testing (defined as a 5 mm graft interface displacement) revealed significantly greater ultimate strength for the TL (557 N) versus the CAL (392 N) ( $P = .010$ ). It was concluded that initial fixation stability is significantly poorer with the CAL when compared to the TL approach.

However, a criticism of Giles et al’s study of proponents of the CAL technique is that the authors did not consider that most surgeons leave the patients immobilized with a sling for the first four to six weeks to facilitate coracoid graft consolidation. Therefore, the graft during that time



**Fig. 2** Bone consolidation. Axial view of the (A) traditional Latarjet (TL) and the (B) congruent-arc Latarjet (CAL). The figure shows that with the TL an average of 15 mm of the graft is in contact with the anterior glenoid (red line). Instead, an average of 10 mm of the graft is in contact with the anterior glenoid with the CAL (green line).

is not subjected to excessive stress and once the graft has healed, both constructs will be equally strong.<sup>21</sup>

Regarding stability, since the inferior surface of the coracoid used with the CAL is wider than the lateral edge of the coracoid used with the classic technique the defenders of the CAL argue that this variant is preferable since it provides a greater bone-blocking effect.<sup>13,22</sup> In a biomechanical cadaveric study, Boons et al<sup>22</sup> compared the TL technique and the CAL modification in terms of glenohumeral stability after reconstruction of a 30% defect. It was concluded that, in abduction external rotation, using the CAL resulted in significantly greater anterior humeral head translation compared to the TL (9.9 and 6.5 mm, respectively,  $P < .013$ ) before reaching a stable non-dislocated endpoint. However, a recent study found no significant differences regarding the stability provided by both techniques.<sup>23</sup> The authors produced a 25% bony lesion in 14 cadaveric shoulders and compared the difference in force required to dislocate the shoulder after reconstruction with the TL and CAL procedures. An anteroinferior force was applied whilst the arm was in abduction and external rotation using a pulley system. The authors reported that the average force required to dislocate the shoulder after the classic Latarjet was 325.71 N, compared with 327.14 N after the congruent-arc technique, and this difference was not statistically significant.<sup>23</sup>

### Bone consolidation

Some anatomical studies showed that the TL could have advantages in terms of bone consolidation compared to the CAL. This is because with this variant, the undersurface of the coracoid that is wider remains in contact with the anterior edge of the glenoid, increasing the contact surface between both bones and thus facilitating bone consolidation. A study carried out by Terra et al<sup>14</sup> specifically measured the sizes of the different faces of the coracoid on 30 cadaveric shoulders, reporting an average value

of 2.11 cm for the undersurface of the coracoid and an average of 1.49 cm for the medial border. Therefore, bone consolidation is favoured with the TL technique, where the inferior surface of the coracoid is in contact with the anterior face of the glenoid, thus allowing a greater contact area between the bones. In contrast, with the CAL, the area that remains in contact with the anterior edge of the glenoid is the medial edge of the coracoid, which is significantly narrower (Fig. 2). Consequently, there is a smaller contact surface between the two bones, possibly resulting in an increased risk of nonunion. Similar results have been reported by other authors. A study conducted by Montgomery et al<sup>12</sup> on 20 pairs of cadaveric shoulders compared the two Latarjet techniques in terms of the area available for fixation. For the TL procedure, the authors reported a mean surface area available for fixation of  $263 \pm 63 \text{ mm}^2$  compared to  $177 \pm 63 \text{ mm}^2$  for the CAL group ( $P < .001$ ). As a result, it was concluded that the TL provided the glenoid with a greater surface area for healing.

However, it is not clear in the literature which is the minimum contact necessary between the coracoid graft and the glenoid to achieve bone consolidation. The rates of nonunion reported in the longest series in the literature with each technique are similar and vary between 8% and 12% for the TL<sup>24,25</sup> and 5% and 15% for the CAL.<sup>26,27</sup> Therefore, it is possible that although the contact area between the graft and the glenoid is smaller with the CAL, it is still sufficient to achieve adequate bone consolidation.

### Graft lysis and resorption

Partial lysis of the coracoid occurs frequently, but only rarely leads to persistent apprehension and unsatisfactory results, and is not considered a complication by most authors but an expected biological reaction to the process of bone consolidation described by Wolff.<sup>28–30</sup> Wolff's law argues that bone density changes in response to the change in functional force acting on bone. The theory is



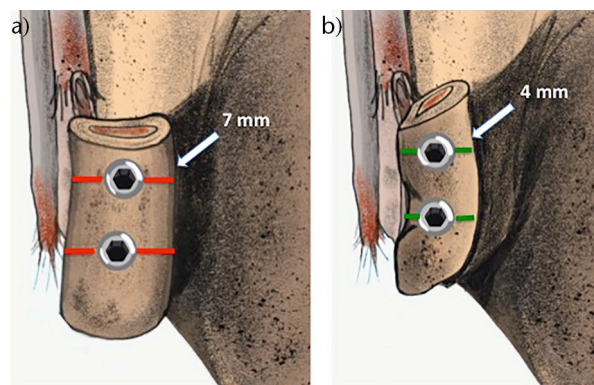
supported by the observation that bone atrophies when it is not supported by mechanical stress and hypertrophy when subjected to tension.<sup>28</sup> The resorption most commonly involves the upper and superficial part of the coracoid.<sup>29,30</sup> The complete reabsorption of the graft is very uncommon and has been described in less than 1% of cases.<sup>31,32</sup> Coracoid graft has been reported to undergo significantly more osteolysis in patients without previous glenoid bone defects compared to those with significant glenoid bone loss (> 20%).<sup>29,30</sup> One possible explanation for these findings is that, as mentioned above, according to Wolff's law, bone that is not under load is reabsorbed due to lack of stimulation. However, studies show that patients who presented greater resorption of the bone block did not present greater instability or recurrences than patients with less resorption.<sup>29</sup> In order to determine the location and the amount of coracoid graft osteolysis, a computed tomography scan study was conducted by Di Giacomo et al,<sup>29</sup> in 26 patients who were prospectively followed up after having undergone the Latarjet procedure. Although a partial graft resorption was reported in 93% of the patients, an excellent or good result was obtained in 92% of the patients, according to the Rowe score, and the shoulder simple test (SST) revealed that 92.3% of the patients were satisfied with the results of the surgery. In addition, there were no reports of failure, which was defined as recurrent dislocation, subtle instability, pain, or stiffness. According to the authors, this result may be attributed to the compensatory mechanism provided by the joint tendon and the capsule suture to the remnant of the coracoacromial ligament.<sup>29,30</sup>

Some authors argue that the CAL has advantages in terms of stability, since by reconstructing the glenoid beyond its original size, it would provide a greater bone-blocking effect, increasing stability.<sup>9,13,21</sup> This issue has sparked controversy in the literature, however, since many studies have shown that, over time, the bone graft is remodelled and the glenoid cavity returns to its original size. In a recent study by Xu et al,<sup>33</sup> coracoid graft remodelling was evaluated by means of computed tomography after a minimum follow-up period of three years in 102 patients who had undergone the Latarjet procedure. It was found that the postoperative three-year graft volumes changed, on average, to  $92.7\% \pm 6.9$ , compared to the volumes obtained immediately after the operation. Graft absorption was observed mostly on the edge and outside the 'best-fit' circle of the glenoid, and most glenoids returned to their original size.

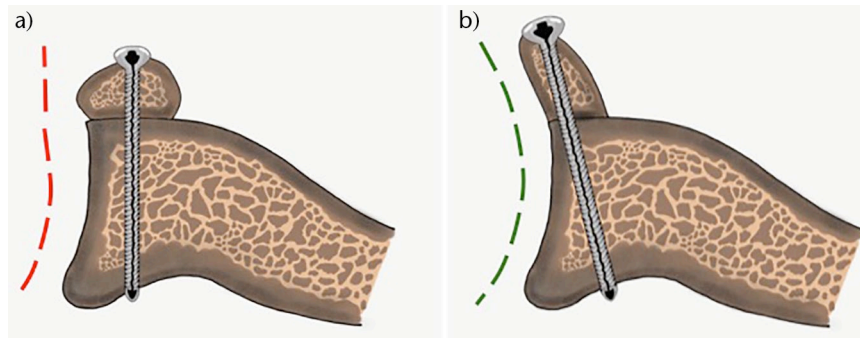
### Technical complexity and possible associated early complications

Some authors argue that the CAL is more technically demanding and is also associated with an increased risk of graft fragmentation. The rationale behind this assumption

is that the width of bone surrounding screw fixation may be decreased, making screw placement difficult and favouring graft fractures in the postoperative period. A study conducted by Dumont et al<sup>10</sup> used computed tomography to compare the TL and the CAL techniques in 24 shoulders in terms of the surface area available for bony contact and the bone width on each side of Latarjet fixation screws of 3.5 mm. The mean bone width on each side of a 3.5-mm screw was  $7.1 \pm 1.0$  mm and  $4.1 \pm 1.0$  mm for the TL technique and the CAL technique, respectively ( $P < .001$ ) (Fig. 3). It was then concluded that the CAL technique is potentially less tolerant of screw-positioning error than the TL technique since the former provides a shorter bone distance around the screw. Consequently, there are two important findings resulting from this study. First, as concluded by the authors, the congruent-arc modification is potentially less tolerant of screw-positioning error, which is a relevant finding given that the Latarjet procedure has been proven to have a long learning curve. Ekhtiari et al,<sup>34</sup> in a recent systematic review, evaluated the learning curve of the Latarjet procedure and reported that a minimum of 22 open and 40 arthroscopic Latarjet procedures are necessary for surgeons to achieve a level of proficiency. Moreover, the congruent-arc modification may be very difficult to perform in patients with very small coracoids, such as small women or skeletally immature patients. On the other hand, with only 4.1 mm of bone remaining on either side of the screws, the wall of the screw tunnel is potentially more likely to fracture with the CAL than with the TL where the wall is on average 7.1 mm.<sup>10</sup> An option proposed by some authors regardless of the technique utilized is the use of suture-buttons to fix the graft and thus decrease the complications associated with the screws. Boileau et al<sup>35</sup> recently evaluated 121 patients who underwent an arthroscopic Latarjet



**Fig. 3** Coronal view of (A) the traditional Latarjet (TL) and (B) the congruent-arc Latarjet (CAL). On average, there are 7 mm of bone between the screw and the lateral and medial wall of the graft with the TL (red lines). Instead, there are on average 4 mm of bone between the screw and the lateral and medial wall of the graft with the CAL (green lines).



**Fig. 4** Axial view of the (A) traditional Latarjet (TL) and the (B) congruent-arc Latarjet (CAL). The radius of curvature of the inferior face of the coracoid graft (green dashed line (used with the CAL) is more similar to the radius of curvature of the native glenoid than the radius of curvature of the medial border of the coracoid (used with the TL).

procedure for recurrent glenohumeral instability where the graft was fixated with a suture-button. The authors reported no hardware-related complications and there was no need for hardware removal after suture-button fixation in any patient. However, until now, there are no biomechanical studies comparing fixation strength between both techniques using buttons.

### Risk of future arthropathy

Regarding postoperative osteoarthritis, long-term follow-up studies have reported significant rates of glenohumeral arthropathy after the Latarjet procedures.<sup>36,37</sup> Allain et al<sup>36</sup> and Hovelius et al<sup>37</sup> examined the results at 15 years and 25 years after the Latarjet procedure and reported 19% and 14% of moderate and severe osteoarthritis, respectively. Recently, in 2019, Hurley et al in a systematic literature review, evaluated long-term osteoarthritis after Latarjet surgery in 11 studies (541 patients) with a minimum follow up of 10 years.<sup>6</sup> After a final average follow up of 16.6 years, there were arthritic changes in 38.2% of the patients. Some biomechanical and anatomical studies have shown that the concavity of the undersurface of the coracoid had a radius of curvature that perfectly matched the radius of curvature of the glenoid (Fig. 4). Armitage et,<sup>13</sup> showed this in a computed tomography anatomy study that found that the radius of the curvature of the inferior coracoid surface was not statistically different ( $P > .05$ ) from the curvature of the native anterior glenoid rim (13.6 vs. 13.8 mm, respectively). Therefore, in theory, the CAL would decrease the contact pressure between the humerus and the glenoid cavity, reducing the risk of arthropathy. In a study conducted by Ghodadra et al<sup>11</sup> on the alterations in glenohumeral contact pressure associated with the two coracoid graft positions, it was found that, with the CAL technique, the mean peak contact pressure was restored to 120% by the bone grafts, compared to 137% with the TL technique ( $p < 0.04$ ). This led the authors to

conclude that glenohumeral contact pressures were optimally restored by a flush coracoid graft with the inferior aspect of the coracoid becoming the glenoid surface.<sup>11</sup> In turn, Giles et al<sup>20</sup> also compared the two Latarjet techniques in terms of contact pressures between the glenoid and the humeral head following glenoid reconstruction of 25% anterior bone defects. An analysis of the contact area revealed that with the TL technique, the humeral head initially made contact with the stiff cortical bone of the coracoid graft over a smaller area. As a result, this contact with the incongruous graft caused a characteristic pressure concentration between the graft and humeral articular cartilage. In contrast, according to the authors, using the CAL technique resulted in better contact characteristics, which might reduce the adverse effects of abnormal joint stresses in the long term. Unfortunately, there are no studies evaluating the incidence of osteoarthritis in the long term with the CAL. Long-term comparative clinical studies with a sufficient number of patients are necessary to verify whether the advantages demonstrated by the CAL in the laboratory are carried over to the clinical setting.

### Conclusions

A summary of the advantages and disadvantages of each technique is shown in Table 1. Current clinical evidence comparing both techniques is very limited. However, from an anatomical and biomechanical perspective, the congruent-arc Latarjet has the advantage of the ability to reconstruct larger bone defects and to decrease contact pressures across the glenohumeral joint. On the other hand, the traditional Latarjet has the advantages of a greater contact surface between the graft and the glenoid, which could facilitate bone consolidation, and a greater distance between the medial and lateral graft walls and the screws, which facilitates the surgical technique and could decrease the chances of fragmenting the graft when placing the screws.

**AUTHOR INFORMATION**

Hospital Italiano de Buenos Aires, Buenos Aires City, Argentina.

Correspondence should be sent to: Luciano A. Rossi, Peron 4190 (C1199ABB), Buenos Aires, Argentina.

Email: luciano.rossi@hospitalitaliano.org.ar

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**REFERENCES**

1. Willemot LB, Elhassan BT, Verborgt O. Bony reconstruction of the anterior glenoid rim. *J Am Acad Orthop Surg* 2018;26:e207–e218.
2. Gowd AK, Liu JN, Cabarcas BC, et al. Management of recurrent anterior shoulder instability with bipolar bone loss: a systematic review to assess critical bone loss amounts. *Am J Sports Med* 2019;47:2484–2493.
3. Cowling PD, Akhtar MA, Liow RYL. What is a Bristow-Latarjet procedure? A review of the described operative techniques and outcomes. *Bone Joint J* 2016;98-B:1208–1214.
4. Yamamoto N, Muraki T, An KN, et al. The stabilizing mechanism of the Latarjet procedure: a cadaveric study. *J Bone Joint Surg Am* 2013;95:1390–1397.
5. Horner NS, Moroz PA, Bhullar R, et al. Open versus arthroscopic Latarjet procedures for the treatment of shoulder instability: a systematic review of comparative studies. *BMC Musculoskelet Disord* 2018;19:255.
6. Hurley ET, Jamal MS, Ali ZS, Montgomery C, Pauzenberger L, Mullett H. Long-term outcomes of the Latarjet procedure for anterior shoulder instability: a systematic review of studies at 10-year follow-up. *J Shoulder Elbow Surg* 2019;28:e33–e39.
7. Hurley ET, Lim Fat D, Farrington SK, Mullett H. Open versus arthroscopic Latarjet procedure for anterior shoulder instability: a systematic review and meta-analysis. *Am J Sport Med* 2019;47:1248–1253.
8. Hurley ET, Montgomery C, Jamal MS, et al. Return to play after the Latarjet procedure for anterior shoulder instability: a systematic review. *Am J Sports Med* 2019;47:3002–3008.
9. Burkhart SS, De Beer JF, Barth JR, Cresswell T, Roberts C, Richards DP. Results of modified Latarjet reconstruction in patients with anteroinferior instability and significant bone loss. *Arthroscopy* 2007;23:1033–1041.
10. Dumont GD, Vopat BG, Parada S, et al. Traditional versus congruent arc Latarjet technique: effect on surface area for union and bone width surrounding screws. *Arthroscopy* 2017;33:946–952.
11. Ghodadra N, Gupta A, Romeo AA, et al. Normalization of glenohumeral articular contact pressures after Latarjet or iliac crest bone-grafting. *J Bone Joint Surg Am* 2010;92:1478–1489.
12. Montgomery SR, Katthagen JC, Mikula JD, et al. Anatomic and biomechanical comparison of the classic and congruent-arc techniques of the Latarjet procedure. *Am J Sports Med* 2017;45:1252–1260.
13. Armitage MS, Elkinson I, Giles JW, Athwal GS. An anatomic, computed tomographic assessment of the coracoid process with special reference to the congruent-arc Latarjet procedure. *Arthroscopy* 2011;27:1485–1489.
14. Terra BB, Ejnisman B, de Figueiredo EA, et al. Anatomic study of the coracoid process: safety margin and practical implications. *Arthroscopy* 2013;29:25–30.
15. Bhatia DN, Kandhari V. Bone defect-induced alteration in glenoid articular surface geometry and restoration with coracoid transfer procedures: a cadaveric study. *J Shoulder Elbow Surg* 2019;28:2418–2426.
16. Tennent DJ, Donohue MA, Posner MA. Bone loss and glenohumeral instability. *Sports Med Arthrosc Rev* 2017;25:131–135.
17. Friedman LGM, Lafosse L, Garrigues GE. Global perspectives on management of shoulder instability: decision making and treatment. *Orthop Clin North Am* 2020;51:241–258.
18. Verweij LPE, Schuit AA, Kerkhoffs GMMJ, Blankevoort L, van den Bekerom MPJ, van Deurzen DFP. Accuracy of currently available methods in quantifying anterior glenoid bone loss: controversy regarding gold standard – a systematic review. *Arthroscopy* 2020;36:2295–2313.e1.
19. Paladini P, Singla R, Merolla G, Porcellini G. Latarjet procedure: is the coracoid enough to restore the glenoid surface? *Int Orthop* 2016;40:1675–1681.
20. Giles JW, Puskas G, Welsh M, Johnson JA, Athwal GS. Do the traditional and modified Latarjet techniques produce equivalent reconstruction stability and strength? *Am J Sports Med* 2012;40:2801–2807.
21. Burkhart SS, DeBeer JF. Traditional and modified Latarjet techniques: letter to the editor. *Am J Sports Med* 2013;41:NP31.
22. Boons HW, Giles JW, Elkinson I, Johnson JA, Athwal GS. Classic versus congruent coracoid positioning during the Latarjet procedure: an in vitro biomechanical comparison. *Arthroscopy* 2013;29:309–316.
23. Prinja A, Raymond A, Pimple M. A biomechanical comparison of two techniques of Latarjet procedure in cadaveric shoulders. *Adv Orthop* 2020;2020:7496492.
24. Garcia JC Jr, do Amaral FM, Belchior RJ, de Carvalho LQ, Markarian GG, Montero EFS. Comparative systematic review of fixation methods of the coracoid and conjoined tendon in the anterior glenoid to treat anterior shoulder instability. *Orthop J Sports Med* 2019;7:2325967118820539.
25. Malahias M-A, Fandridis E, Chytas D, Chronopoulos E, Brilakis E, Antonogiannakis E. Arthroscopic versus open Latarjet: a step-by-step comprehensive and systematic review. *Eur J Orthop Surg Traumatol* 2019;29:957–966.
26. Rossi LA, Bertona A, Tanoira I, Maignon GD, Bongiovanni SL, Ranalletta M. Comparison between modified Latarjet performed as a primary or revision procedure in competitive athletes: a comparative study of 100 patients with a minimum 2-year follow-up. *Orthop J Sports Med* 2018;6:2325967118817233.
27. Ranalletta M, Rossi LA, Bertona A, Tanoira I, Maignon GD, Bongiovanni SL. Modified Latarjet procedure without capsulolabral repair for the treatment of failed previous operative stabilizations in athletes. *Arthroscopy* 2018;34:1421–1427.

- 28. Ruff C, Holt B, Trinkaus E.** Who's afraid of the big bad Wolff? 'Wolff's law' and bone functional adaptation. *Am J Phys Anthropol* 2006;129:484–498.
- 29. Di Giacomo G, Costantini A, de Gasperis N, et al.** Coracoid graft osteolysis after the Latarjet procedure for anteroinferior shoulder instability: a computed tomography scan study of twenty-six patients. *J Shoulder Elbow Surg* 2011;20:989–995.
- 30. Di Giacomo G, de Gasperis N, Costantini A, De Vita A, Beccaglia MAR, Pouliart N.** Does the presence of glenoid bone loss influence coracoid bone graft osteolysis after the Latarjet procedure? A computed tomography scan study in 2 groups of patients with and without glenoid bone loss. *J Shoulder Elbow Surg* 2014;23:514–518.
- 31. Domos P, Lunini E, Walch G.** Contraindications and complications of the Latarjet procedure. *Shoulder Elbow* 2018;10:15–24.
- 32. Gartsman GM, Waggenspack WN Jr, O'Connor DP, Elkousy HA, Edwards TB.** Immediate and early complications of the open Latarjet procedure: a retrospective review of a large consecutive case series. *J Shoulder Elbow Surg* 2017;26:68–72.
- 33. Xu J, Liu H, Lu W, et al.** Modified arthroscopic Latarjet procedure: suture-button fixation achieves excellent remodeling at 3-year follow-up. *Am J Sports Med* 2020;48:39–47.
- 34. Ekhtiari S, Horner NS, Bedi A, Ayeni OR, Khan M.** The learning curve for the Latarjet procedure: a systematic review. *Orthop J Sports Med* 2018;6:2325967118786930.
- 35. Boileau P, Saliken D, Gendre P, et al.** Arthroscopic Latarjet: suture-button fixation is a safe and reliable alternative to screw fixation. *Arthroscopy* 2019;35:1050–1061.
- 36. Allain J, Goutallier D, Glorion C.** Long-term results of the Latarjet procedure for the treatment of anterior instability of the shoulder. *J Bone Joint Surg Am* 1998;80:841–852.
- 37. Hovelius L, Saeboe M.** Neer Award 2008: arthropathy after primary anterior shoulder dislocation—223 shoulders prospectively followed up for twenty-five years. *J Shoulder Elbow Surg* 2009;18:339–347.