Technical Note

Use of 3D-Printed Patient-Specific Guide for Latarjet Procedure in Patients With Anterior Shoulder Instability: Technical Note

Vitor La Banca, M.D., Luiz Giglio, M.D., Ana Victória Palagi Viganó, M.D., Luiz Fernando Michaelis, M.D., João Artur Bonadiman, M.D., Guilherme Henrique Vieira Lima, M.D., and Roberto Yukio Ikemoto, M.D., Ph.D.

Abstract: Anterior shoulder instability can lead to anterior glenoid bone loss associated with humeral posterior deformity (bipolar bone loss). Latarjet procedure is a commonly used surgical option in such cases. However, the procedure is associated with complications in up 15% of the cases often associated with inadequate positioning of coracoid bone graft and screws. Considering that acknowledgment of patient anatomy and use of surgical planning intraoperatively can reduce such complications, we describe the use of 3D printing tools to obtain a 3D Patient-Specific Surgical Guide to aid in the Latarjet procedure. Such tools present advantages and limitations compared to other tools available, which are also discussed in this article.

Introduction

Latarjet surgery is one of the most performed surgical procedures for treating shoulder instability associated with the anterior glenoid bone loss.[1] It was described by Michel Latarjet in 1954[2] and, since then, significant changes have been described. Among them, are changes in graft positioning and, more recently, executions with arthroscopic vision.[3,4]

Some frequent complications of the procedure are related to the positioning of the bone graft, which can be very medialized or lateralized (intra-articular),[5] and related to implants used, such as graft fractures due to manipulation, perforation, and/or compression by the screws.

3D printing (Additive Manufacturing) tools applied to orthopedic procedures have been recently described in several orthopedic procedures.[6] One of the applications of this technology is the development of patient-specific surgical guides.[6] Such guides allow the surgeon to evaluate patient anatomy, plan surgical steps (osteotomies or implant positioning), and transpose this plan to the surgical site intraoperatively. In the context of shoulder surgery, the use and efficiency of 3D patient-specific guides has been described by other authors for shoulder arthroplasty.[7-9]

Considering its potential to reduce complications and improve graft positioning, as observed in other shoulder procedures, we aimed to develop a patient-specific guide for the Latarjet procedure. In this technical note, we describe the surgical technique of a Latarjet procedure with the use of a 3D-printed patient-specific instrument (PSI).

Surgical Technique

This report received Institutional Review Board approval on December 21, 2021, with the following protocol CAAE 54172821.7.0000.5488.

From the Orthopedic Surgery Department, Centro Universitário Faculdade de Medicina do ABC (FMABC), São Paulo, Brazil (V.L., L.G., A.V.P.V., L.F.M., G.H.V.L., R.Y.I.); Instituto Brasil de Tecnologias da Saúde (IBTS), Rio de Janeiro, Brazil (V.L., J.A.B.); Hospital Ipiranga, São Paulo, Brazil (L.G., A.V.P.V., G.H.V.L., R.Y.I.).

The authors report the following potential conflicts of interest or sources of funding: V.L. reports consulting fees for 3D printing orthosis research from Hefesto Medtech, outside the submitted work. L.F.M. reports consulting fees for 3D printing orthosis research from Hefesto Medtech, outside the submitted work. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received November 1, 2022; accepted February 12, 2023.

Address correspondence to Vitor La Banca, M.D., R. da Consolação, 222 - Centro Histórico de São Paulo, São Paulo - SP, Brazil. E-mail: labanca.vitor@gmail.com

2212-6287/221448

https://doi.org/10.1016/j.eats.2023.02.027

Patient Evaluation, Imaging, and Indications

Patient's clinical history is obtained, with special attention given to age of first shoulder dislocation, number of episodes, and degree of pain and/or established limitations. Level of participation (amateur or professional) in contact or noncontact sports is also noted, as well as patient's expectations with treatment.

Upon clinical examination, range of motion is assessed by evaluating the presence of hyperlaxity signs or any subsequent stiffness. Physical examination tests, such as the sulcus sign, the apprehension test, the relocation tests, and others may be performed to reproduce patient symptoms and help to interpret underlying pathology.

Radiographic shoulder series, shoulder computer tomography (CT), and shoulder magnetic resonance imaging (MRI) are obtained to better evaluate injured shoulder structures. Radiographs of the shoulder are evaluated for the presence of secondary shoulder arthritis, presence of large bone erosions on the humerus and on the anterior glenoid, and possible subluxation of the shoulder joint. MRI is mostly used for assessment of the anterior labrum, associated capsular injury, and rotator cuff status. On shoulder CT, it is possible to determine the presence and proportion of anterior glenoid bone loss, as well as the presence and extension of Hill-Sachs lesion (Fig 1).

Clinical status, patient expectations, and exam findings are considered for surgical indication. Factors that guide the choice between labral repair (and other soft tissue procedures) or bone graft transfers (such as the Latarjet procedure) are extensively debated in the literature[1] and are beyond the scope of this report, but the authors consider anterior glenoid bone loss >15%, offtrack bipolar bone loss,[10] ISIS Score >6[11] as major criteria for surgical treatment with the Latarjet technique.

This report was approved by the Institution's Ethics Committee (CD CAAE 54172821.7.0000.5488).

Planning and Guide Development

Using the DICOM (Digital Communications in Medicine) file of the shoulder CT, we perform three-dimensional reconstructions of the bone surfaces of the patient's shoulder using the software InVesalius (CTI Renato Archer, Campinas, SP, Brazil). We perform the file segmentation process, where we selected only the structures of interest—in this case, the scapula, comprising the glenoid and coracoid process—using the open software MeshMixer (Autodesk, Inc., San Rafael, CA, USA) (Fig 2).

From the digital reconstruction of the patient's scapula, we perform a digital simulation of the osteotomy of the coracoid process using Fusion software (Autodesk, Inc., San Rafael, CA). The osteotomy was simulated perpendicular to the coracoid longest axis, at its inferior cortical inflection point, known as the "knee" of the coracoid process (Fig 3).

With the coracoid graft planned, it is digitally positioned on the anteroinferior border of the glenoid (Fig 4). With the graft positioned, two cylinders are created, representing 1.25-mm guide wires for cancellous screw drill. The planned guide wires are positioned respecting 7-mm distance to graft cortical, coracoid medial to lateral desired position (offset), and inclination relative to the glenoid surface. The planned graft and implant position is confirmed.

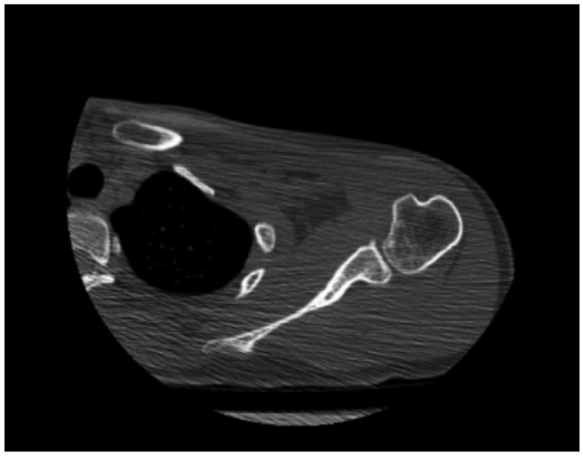

Fig 1. Axial view of shoulder computed tomography scan. It is possible to observe anterior inferior glenoid bone loss.

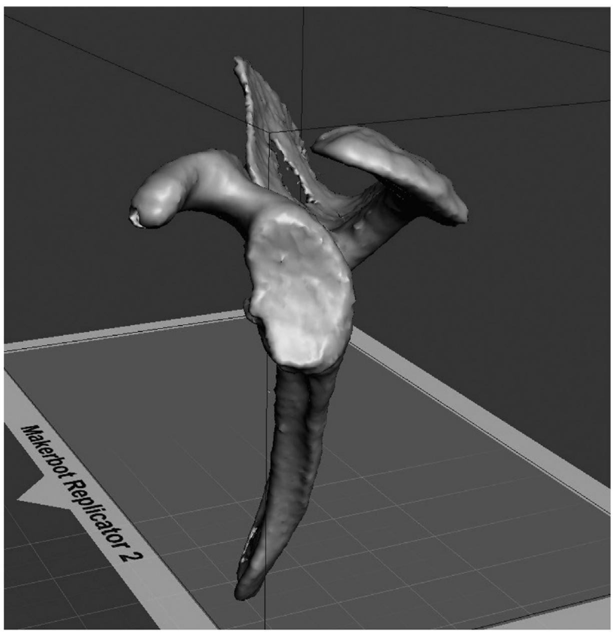

Fig 2. Lateral view of scapula three-dimensional bone reconstruction with suppressed humeral side, showing glenoid anterior inferior bone loss.

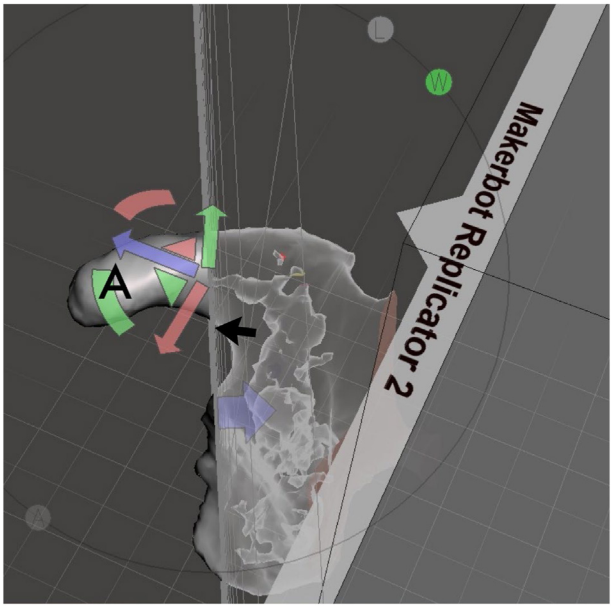

Fig 3. Anterior superior view of scapula three-dimensional bone reconstruction. Planned osteotomy position and inclination on the coracoid process (arrow) and resulting coracoid graft (A).

Using CAD tools, we designed a guide around the coracoid graft superior surface (CorG), as to allow passage of the planned 1.25-mm guide wires through the graft (Fig 5). The guide is designed to perfectly adapt to the coracoid shape.

Fig 4. Lateral view of scapula three-dimensional bone reconstruction with suppressed humeral side. Planned coracoid graft (A) is positioned on the glenoid (*) anterior inferior border.

Fig 5. Anterior lateral view of coracoid graft three-dimensional reconstruction and planned coracoid PSI guide (CG) for coracoid drilling. A denotes planned coracoid graft.

The graft digital object is removed from the 3D reconstruction, and in a similar fashion, a guide is designed around the glenoid anterior rim and anterior surface (GlenG), with holes for the passage of guide wires into the planned position (Fig 6). A handle is added to the GlenG to facilitate guide manipulation and positioning intraoperatively. This handle is canulated to allow guide temporary fixation in the glenoid neck during the procedure.

The guides are printed by Hefesto MedTech (Hefesto MedTech, Sao Paulo, Brazil) in a fused deposition modeling, or FDM, technology 3D printer. A real-size 3D model of the glenoid, coracoid, and affected bone

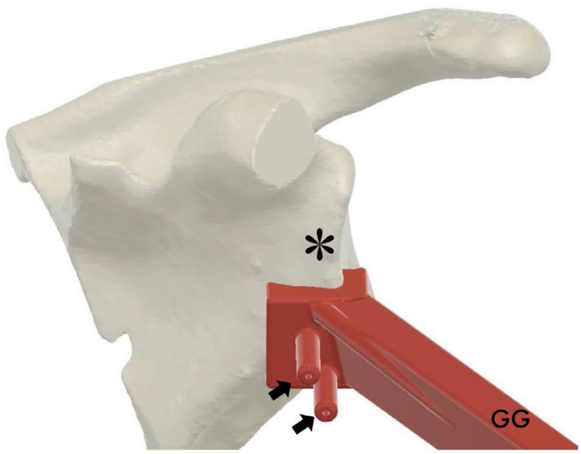

Fig 6. Anterior view of glenoid 3D reconstruction (*). The glenoid PSI guide (GG) designed around the planned guide wires position (arrows) and glenoid anterior inferior border.

Fig 7. 3D Printed guides and segmented scapula 3D printed model.

is also printed, meant to be used as guide testing, validation, and surgical team education preoperatively (Fig 7).

Patient Positioning and Anesthesia

General anesthesia with brachial plexus nerve block is performed. The patient is positioned in a standard beach chair position, allowing free movement of the shoulder (Fig 8). A rolled pad is added to the medial border of the scapula in order to protract it and facilitate glenoid exposure and access. Special attention is given to provide good fluoroscopy images of the shoulder joint, as those might be necessary. Antibiotic prophylaxis is performed prior to surgical incision.

Fig 8. Clinical image of patient positioned in beach chair position, with free access to the shoulder.

Surgical Technique

A conventional deltopectoral approach is performed. The coracoid process is identified and exposed (Fig 9). The coracoacromial ligament is identified and excised 1 cm from the lateral border of the coracoid, and the pectoralis minor tendon is excised from the medial border of the coracoid. The osteotomy of the coracoid process is performed with an oscillating saw (Stryker, Kalamazoo, MI) considering as a reference the junction of the vertical and horizontal portions of its lower cortex (“knee of the coracoid”). The graft obtained is prepared by removing cortical bone from its lower surface, exposing cancellous bone, with the aid of an oscillating saw. The CorG is adapted to the superior surface of the coracoid process graft, and two 1.25-mm threaded guide wires for a 2.7-mm drill (DePuy Synthes, West Chester, PA) are passed through the guide into the graft (Fig 10). CorG is removed, the position of the guide wires is confirmed, and a 2.7-mm cannulated drill is passed through the wires. The coracoid graft is placed posterior to the pectoral major muscle to be protected and retrieved later on.

The shoulder is then positioned in abduction and lateral rotation, and the split of the subscapularis

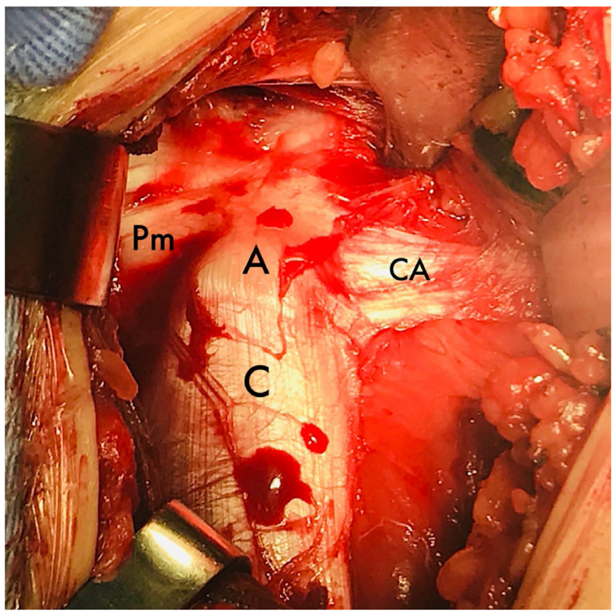

Fig 9. Anterior view of deltopectoral approach. Coracoid process (A) is exposed with the coracoacromial ligament (CA), pectoralis minor tendon (Pm), and conjoint tendon (C) attachments.

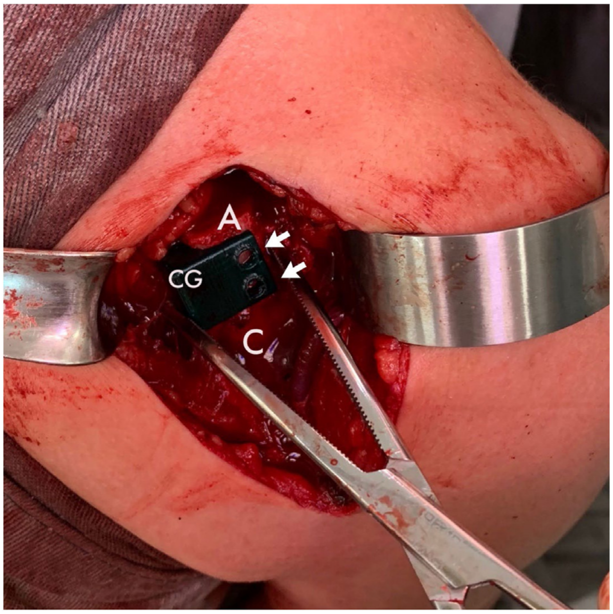

Fig 10. Anterosuperior view of deltopectoral approach. Coracoid guide (CG) is adapted to coracoid graft (A) after osteotomy with conjoint tendon (C) attached to the graft inferiorly. The holes on the CG (arrows) guide the passage of 2.7-mm drill through the graft.

tendon is performed, followed by the opening of the capsule, excision of the labrum (Fig 11), and exposure of the anteroinferior border of the glenoid and its articular surface with assistance of a Fukuda and glenoid retractors. A 2.5-mm K wire may be used for superior subscapularis muscle belly retraction and glenoid anterior neck exposure.

The GlenG is then positioned against the glenoid anterior border and articular surface to adapt to its anterior rim, under direct vision, and provisionally fixed to the glenoid neck with a 2.0-mm Kirchner wire through the handle hole designed for this purpose.

With the guide in place, two 1.25-mm guide wires for a 2.7-mm drill (DePuy Synthes, West Chester, PA) are passed through the guide into the glenoid (Fig 12). With the two guide wires in place, the GlenG is removed, and the proper wire position is confirmed (Fig 13).

Sequentially, the coracoid graft is retrieved and is positioned in order to match the graft holes with the positioned guide wires in the glenoid. In that manner, the coracoid graft can be slid over the guide wires into the glenoid to the proper position against the anteroinferior rim (Fig 14).

Guided by the wires, the graft is pushed against the glenoid neck (Fig 15), while a 2.7-mm cannulated drill is passed through the graft superior hole into the glenoid. A 3.5-mm cancellous cannulated (DePuy Synthes, West Chester, PA) screw is tightened in the superior hole (Fig 16A). The same sequence is performed in the inferior hole (Fig 16B).

Final graft position and fixation are confirmed on fluoroscopy (Fig 17 A and B) and under direct visualization, closure of intermuscular plans is performed. No

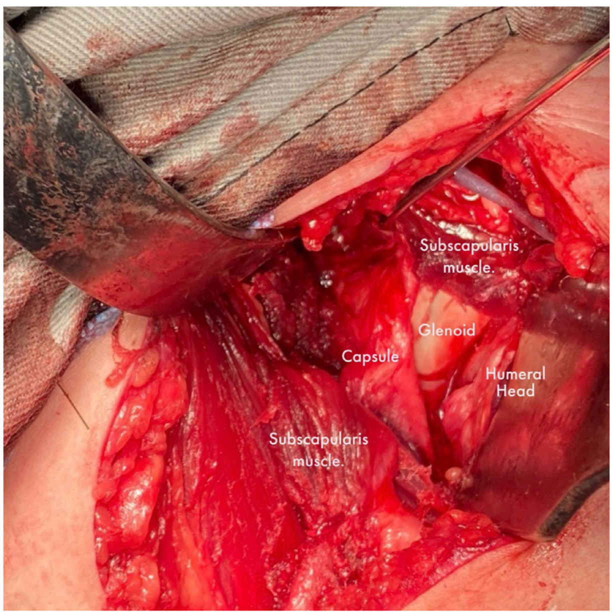

Fig 11. Anterior view of deltopectoral approach. Subscapularis split and capsule opening with exposure of the glenoid medially and the humeral head are retracted laterally. Labrum and partial inferior capsule are still attached to inferior glenoid border.

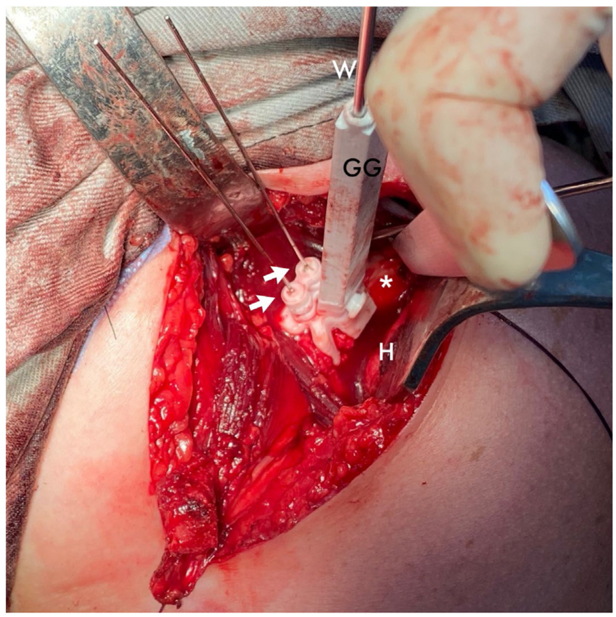

Fig 12. Anterolateral view of deltopectoral approach, humeral head (H) retracted laterally. Glenoid (*) anterior border is exposed and the glenoid guide (GG) is fixed to its anterior inferior border with a 2.0-mm K wire (W). The two 1.25-mm guide wires are passed through the guide holes (arrows).

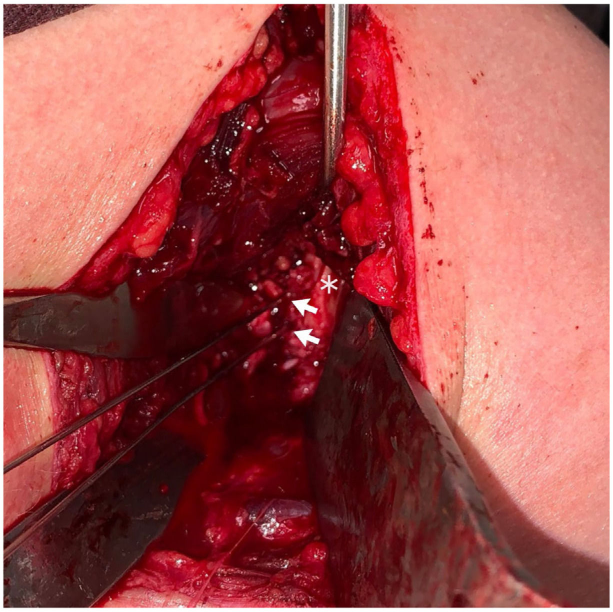

Fig 13. Anterior view of deltopectoral approach, humeral head retracted laterally (to the right). After removal of the glenoid guide, the two 1.25-mm (arrows) guide wires remain on the planned position of the glenoid (*).

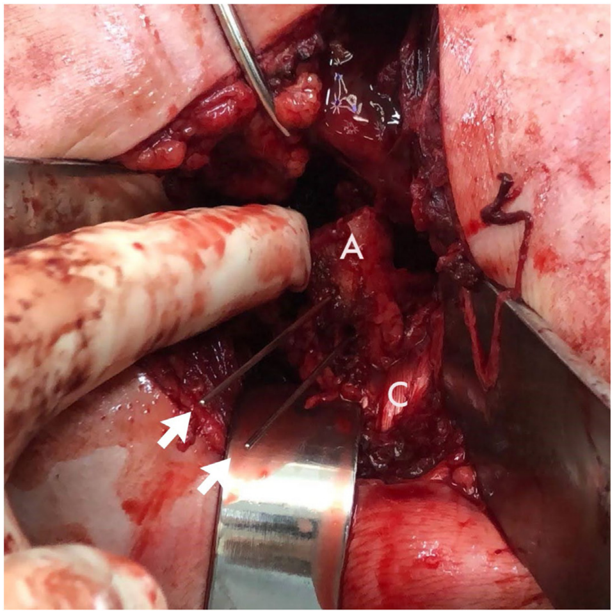

Fig 15. Anterior view of deltopectoral approach with humeral head retracted laterally (to the right). Guided by the wires (arrows), the coracoid graft (A) is placed and maintained into position while a 2.7-mm drill is passed through the wires into the graft and glenoid. Conjoint tendon (C) can be seen already tensioning the inferior subscapularis muscle belly.

drainage is utilized. Surgical steps here described are presented with more details in Video 1.

The patient is placed in a sling for 4 weeks, with passive range of motion allowed after 1 week. With 4-6 weeks, the sling is discontinued, and the patient is allowed to start physical therapy that focuses on active range of motion and strengthening. Return-to-sports activities are expected in 4 to 6 months postoperatively.

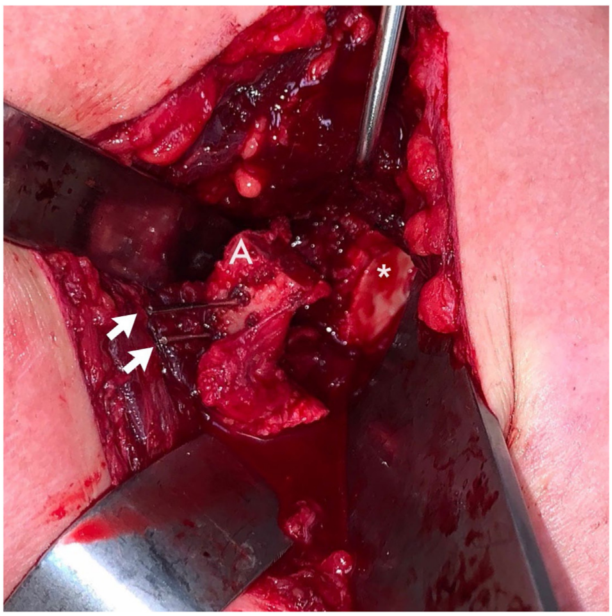

Fig 14. Anterior view of deltopectoral approach with humeral head retracted laterally (to the right) and glenoid (*) medially. Coracoid graft (A) holes are matched with 1.25-mm positioned guide wires (arrows), allowing it to be slid to the anterior inferior border of the glenoid.

Discussion

Latarjet is a useful tool in the treatment of anterior shoulder instability, but it is associated with complications in up to 15-30% of the cases.[5] That considered, meticulous technique and proper knowledge of patient anatomy can reduce incidence of complications.[5] In the technique described, we aimed to implement a method that considered patient anatomy and allowed us to reproduce what was digitally planned, resulting in a good positioning of the graft and screws, in addition to important reproducibility with what was digitally planned.

Barth et al.,[12] in a prospective series, observed that the use of guides for perforating the glenoid can improve graft positioning compared to the direct manipulation technique (freehand technique). They observed more lateral and superior positioning of the graft in the freehand technique in comparison with the guided technique. Similar conclusions were reported by Klatte et al.[13] that evaluated the positioning of the graft with a guide and reported good positioning in relation to glenoid surface. Meyer et al.[14] also reported on good

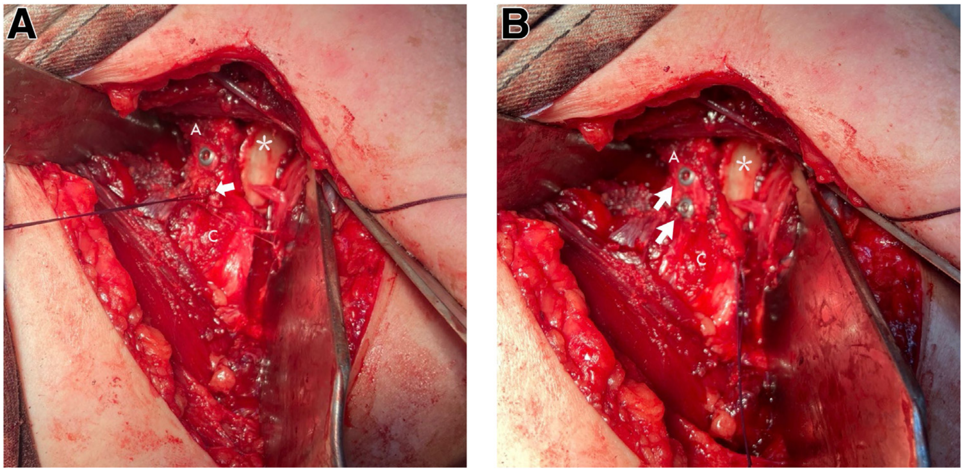

Fig 16. (A) Anterior view of deltopectoral approach with humeral head retracted laterally (to the right) glenoid (*) medially and conjoint tendon (C) inferiorly. The 3.5-mm superior screw is tightened, and the coracoacromial ligament stump (arrow) was prepared to be sutured to the capsular tissue. Planned coracoid graft (A) position is confirmed in relation to glenoid (*) articular surface. (B) Two 3.5-mm screws tightened (arrows) with placement of coracoid graft (A) confirmed under direct visualization.

positioning of graft in his series of 12 consecutive Latarjet procedures with the use of a guide. Different from our technique, however, these previous authors evaluated commercially available guides, used for all patients with small adaptation capacity. Anatomical differences in size and shape of the glenoid and coracoid process are described for different populations and gender,[15,16] and, therefore, we understand that the customized guide can potentially lead to even superior results concerning the positioning of the graft and implants.

3D printing in healthcare is a growing field,[6] and especially in orthopedic surgery, it has been implemented and studied.[17] 3D-printed guides in shoulder surgery have been used and studied for positioning of glenoid components in shoulder arthroplasty[7-18] and less frequently for fractures[19] and corrective osteotomies.[20] To this point, we have not found other reports on the use of 3D Printed PSI guides for Latarjet surgery.

Moreover, the perception of the team involved in the procedure was that the use of the guide makes the surgical steps faster and less technically demanding in comparison to the conventional technique, and it reduced the need for fluoroscopy images. Some potential advantages and disadvantages of the described technique are listed in Table 1.

Finally, this is a customizable method, and so, the technique described could potentially be adapted to other Latarjet procedure alterations, such as the congruent Arc modification,[3] or arthroscopic assisted procedure,[4] if necessary. Further research with a larger number of cases and comparison of this method with standard and other available techniques may allow for

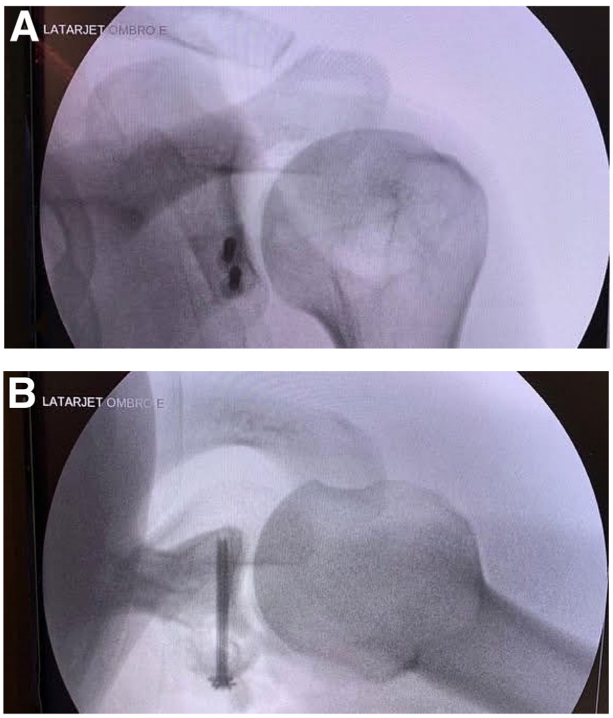

Fig 17. (A) Intraoperative fluoroscopy AP view of the shoulder. Graft anterior inferior positioning and screw position are confirmed. (B) Intraoperative fluoroscopy. Axial view of the shoulder. Medial to lateral position of the graft and screws inclination in relation to the glenoid articular surface is confirmed.

Table 1. Technique Advantages and Disadvantages

Advantages	Disadvantages
Guide is designed specifically for patient singular bone anatomy.	Larger exposure may be necessary to correctly adapt PSI guides.
Increased accuracy to graft and implant positioning relative to preoperative plan.	Increased time to surgery to permit guide planning and manufacturing
Decreased need for fluoroscopy intraoperatively	Increased costs compared to the free-hand technique
Decreased surgical time	

PSI, patient-specific instrument.

more conclusions on the accuracy and reproducibility of the method.

Conclusion

We present an innovative tool for positioning and fixing the coracoid process graft in the Latarjet procedure. We understand that, together with other resources, three-dimensional planning and the use of 3D guides are a natural evolution of classic orthopedic surgical planning and consequent improvement in technical execution. More clinical studies are needed to better assess accuracy and reproducibility of this technique.

Acknowledgments

The authors would like to acknowledge Henrique de Lazari Schaffhauser, Luis Gustavo Prata Nascimento, Vitor Urel Carneiro, João Victor de Araujo Silva, and Caique Kranholdt Ferreira for the aid in the development of this technique and this report.

References

1. Arner JW, Peebles LA, Bradley JP, Provencher MT. Anterior shoulder instability management: Indications, techniques, and outcomes. *Arthroscopy* 2020;36:2791-2793.
2. LATARJET M. Treatment of recurrent dislocation of the shoulder. A propos du traitement des luxations récidivantes de l'épaule. *Lyon Chir* 1954;49:994-997 [in French].
3. Pasqualini I, De Cicco FL, Tanoira I, Ranalletta M, Rossi LA. Classic versus congruent-arc Latarjet procedures. *Arthroscopy* 2023;39:8-10.
4. Castricini R, Castioni D, De Benedetto M, et al. Arthroscopic Latarjet for primary shoulder instability with off-track lesions or revision surgery yields satisfactory clinical results and reliable return to sport and work at minimum 3-year follow-up. *Arthroscopy* 2022;38:2809-2818.e1.
5. Domos P, Lunini E, Walch G. Contraindications and complications of the Latarjet procedure. *Shoulder Elbow* 2018;10:15-24.
6. Beredjiklian PK, Wang M, Lutsky K, Vaccaro A, Rivlin M. Three-dimensional printing in orthopaedic surgery: Technology and clinical applications. *J Bone Joint Surg Am* 2020;102:909-919.
7. Cabarcas BC, Cvetanovich GL, Espinoza-Orias AA, et al. Novel 3-dimensionally printed patient-specific guide improves accuracy compared with standard total shoulder arthroplasty guide: A cadaveric study. *JSES Open Access* 2019;3:83-92.
8. Ward BE, Dines JS. Patient-specific guides/instrumentation in shoulder arthroplasty. *Am J Orthop (Belle Mead NJ)* 2018;47. https://doi.org/10.12788/ajo.2018.0013.
9. Gauci MO. Patient-specific guides in orthopedic surgery. *Orthop Traumatol Surg Res* 2022;108, 103154.
10. Schwihla I, Wieser K, Grubhofer F, Zimmermann SM. Long-term recurrence rate in anterior shoulder instability after Bankart repair based on the on- and off-track concept. *J Shoulder Elbow Surg* 2023;32:269-275.
11. Verweij LPE, van Spanning SH, Grillo A, et al. Age, participation in competitive sports, bony lesions, ALPSA lesions, >1 preoperative dislocations, surgical delay, and ISIS score >3 are risk factors for recurrence following arthroscopic Bankart repair: A systematic review and meta-analysis of 4584 shoulders. *Knee Surg Sports Traumatol Arthrosc* 2021;29:4004-4014.
12. Barth J, Boutsiadis A, Neyton L, Lafosse L, Walch G. Can a drill guide improve the coracoid graft placement during the Latarjet procedure? A prospective comparative study with the freehand technique. *Orthop J Sports Med* 2017;5: 2325967117734218.
13. Klatte TO, Hartel MJ, Weiser L, et al. Accuracy of Latarjet graft and screw position after using novel drill guide. *Eur J Trauma Emerg Surg* 2017;43:645-649.
14. Meyer DC, Moor BK, Gerber C, Ek ET. Accurate coracoid graft placement through use of a drill guide for the Latarjet procedure. *J Shoulder Elbow Surg* 2013;22: 701-708.
15. du Plessis JP, Dey R, Dachs R, et al. A gender-based comparison of coracoid and glenoid anatomy: CT analysis and discussion of potential impact on the Latarjet procedure. *J Shoulder Elbow Surg* 2021;30:1503-1510.
16. Alves BVP, Silva GS, Matsumoto FY, Ferreira MT, Britto AG, Mothes FC. Comparative evaluation of coracoid graft dimensions in the Latarjet surgery for anterior glenohumeral instability. *Rev Bras Ortop (Sao Paulo)* 2020;55:215-220.
17. Bagaria V, Bhansali R, Pawar P. 3D printing—Creating a blueprint for the future of orthopedics: Current concept review and the road ahead! [published correction appears in *J Clin Orthop Trauma* 2020 Nov-Dec;11:1169-1171] [published correction appears in *J Clin Orthop Trauma* 2020;11:1172-1174]. *J Clin Orthop Trauma* 2018;9:207-212.
18. Gauci MO, Boileau P, Baba M, Chaoui J, Walch G. Patient-specific glenoid guides provide accuracy and reproducibility in total shoulder arthroplasty. *Bone Joint J* 2016;98-B:1080-1085.
19. Li K, Liu Z, Li X, Wang J. 3D printing-assisted surgery for proximal humerus fractures: A systematic review and meta-analysis. *Eur J Trauma Emerg Surg* 2022;48: 3493-3503.
20. Meng M, Wang J, Sun T, et al. Clinical applications and prospects of 3D printing guide templates in orthopaedics. *J Orthop Translat* 2022;34:22-41.