



The utilization of computer planning and 3D-printed guide in the surgical management of a reverse Hill-Sachs lesion

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Although glenohumeral dislocation is a relatively common condition, only 2% of all shoulder dislocations are in the posterior direction.^{1,11} Because such dislocations are rare and difficult to radiographically visualize, between 50% and 79% of posterior glenohumeral dislocations are not diagnosed at the initial examination.^{10,11,19} Most of these dislocations occur in men aged between 20 and 49 years¹⁹ after a combined movement involving adduction, flexion, and internal rotation of the arm.^{10,11} Two etiologies account for this condition: two-thirds of cases have a traumatic origin, and the remaining cases have an atraumatic origin related to seizures (due to epilepsy, electrocution, or another condition), hyperlaxity, infantile paralysis (polio), brachial plexus birth palsy, or Ehlers-Danlos disease.^{1,4,11,17-19}

Traumatic episodes can be associated with a wide range of lesions. The present case involved an anterior-superior depression on the surface of the humeral head; this manifestation is known as a reverse Hill-Sachs lesion and is present in 86% of posterior dislocations.⁸

Restoring the joint morphology for these impacted fractures is a challenge for the surgeon. New three-dimensional (3D) imaging, segmentation, and modeling technologies help orthopedic surgeons diagnose the lesion, make decisions, and perform surgery. The present study describes the use of these new tools to manufacture custom guides that enable precise reconstruction of a defect and carving of a custom osteochondral allograft. But this kind of approach, using new technologies, could be applied to any kind of orthopedic challenge. All procedures were performed using free

software; therefore, this treatment method can be reproduced at any hospital center.

Clinical case

We present the case of a 40-year-old man who arrived at the emergency department after an epileptic seizure showing blurred vision, referred pain, and functional limitation of his right shoulder. Standard radiographs were taken (Fig. 1), and he was diagnosed with arthritis of an unknown origin. One month later, pain and a decrease in joint mobility were confirmed. New radiographs were taken (Fig. 2), and a posterior glenohumeral dislocation with an associated reverse Hill-Sachs lesion was diagnosed. Treatment was defined using the algorithm published by Kokkalis et al.¹² As the patient suffered a persistent dislocation and had a high functional demand, optimal treatment involved open reduction and stabilization using a technique dependent on the defect size (30% of the humeral head in our case, according to Moroder et al.¹⁶). Treatment options included rotational osteotomy, the McLaughlin technique, and allograft reconstruction.¹⁶ We opted for a humeral head reconstruction using an osteochondral allograft similar to that described by Gerber and Lambert.⁷

To reduce the surgical time, minimize bone resection, adjust the size of the graft to the defect, and maximize joint congruence, we employed 3D technology to design and print 2 cutting guides used to standardize the process of regularizing the lesion and shaping the graft. To segment the computed tomography (CT) data, 3D Slicer (open source software) was used, resulting in only bone-related data. Once the defect was identified, applicable models were exported to Autodesk Meshmixer (Autodesk Inc., San Rafael, CA, USA) to create 2 cutting templates (Fig. 3). The first one was

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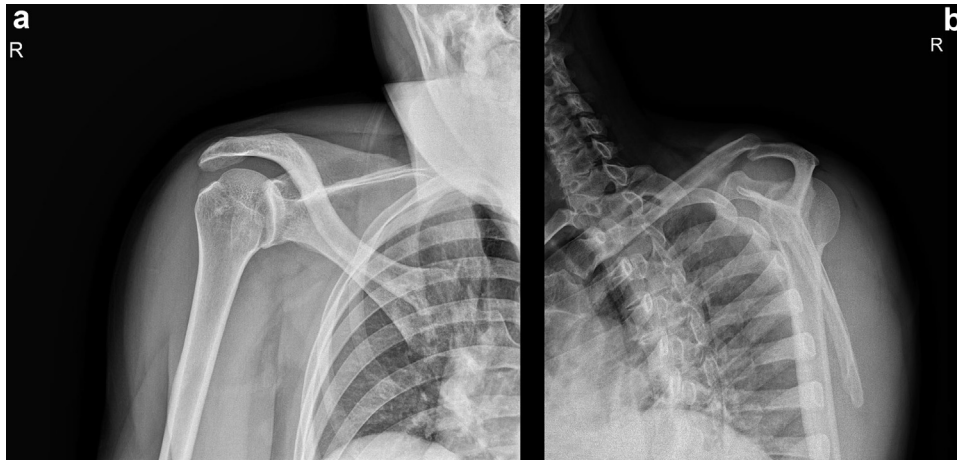


Figure 1 Antero-Posterior view (a) and lateral-view (b) showing undiagnosed posterior dislocation (radiographs taken in the emergency department).

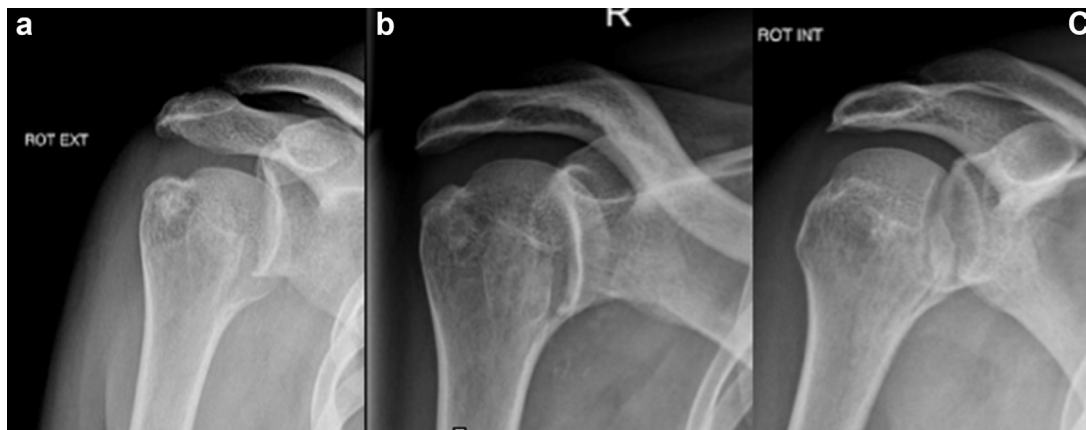


Figure 2 Radiographs taken 1 month after trauma. Posterior dislocation and a reverse Hill-Sachs lesion were detected. (a) Externally rotated radiography. (b) Radiography in neutral position. (c) Internally rotated radiography.

designed to minimize bone resection. Its base was formed as a negative of the Hill-Sachs lesion such that the template would fit over the depression, and its walls would serve to support and guide the oscillating saw (Figs. 4 and 5). The second template was intended to trim a femoral head allograft to the size of the previously reconstructed lesion. Thus, this template was of the same size as the first one but had a concave base that matched the humeral head defect area and that would rest on the convex surface of the allograft (Figs. 6 and 7). The templates were printed from acrylonitrile butadiene styrene resin, and sterilization was performed with ethylene oxide to prevent template deformation due to heat from an autoclave.

Surgery was performed using a standard deltopectoral approach under general anesthesia with the patient in a beach-chair position. Positioning the first cutting template over the defect and fixing it to the underlying bone with Kirschner wires allowed safe resection of the lesion (Fig. 6). The second guide was used on a femoral head from the tissue bank (Fig. 7). The resulting bone and cartilage block was inserted into the already regularized bone defect, where it fit precisely. Three cannulated headless screws were used for final fixation (Figs. 8 and 9, a). Rehabilitation with passive range of motion exercises was initiated on the first postoperative day, and active physiotherapy was incorporated beginning in the third week. Three months later, the patient was asymptomatic and had full joint balance. One year later, the patient was able to return to work,

and imaging studies (Fig. 9, b) showed good joint congruence. The patient's functional outcome was measured using the Disabilities of the Arm, Shoulder, and Hand scale,⁹ and an overall score of 22 points and a labor subscale score of 12.5 were obtained. A score of 92 points was obtained on the Constant³ questionnaire.

Discussion

This case is interesting not only due to the low incidence of posterior shoulder dislocations but also for the methodology used to diagnose and treat the patient. 3D planning and additive manufacturing are new weapons that the surgeon should know and use.

The small number of posterior dislocations and the difficulties associated with their radiographic identification could make those injuries go unnoticed in an initial analysis,^{11,19} as occurred in our case, and a delay in diagnosis worsens the prognosis of the lesion.^{1,10,12} New 3D imaging techniques can improve visualization, thus facilitating the diagnosis and choice of treatment.^{6,13,22}

In the present case, which was not successfully diagnosed in the emergency department, a CT scan showed the relationships between different bone structures in detail, revealing the glenohumeral dislocation and reverse Hill-Sachs lesion.²¹ Several authors recommend using this imaging technique when radiographs are inconclusive,^{10,11,19} and others have noted the importance of

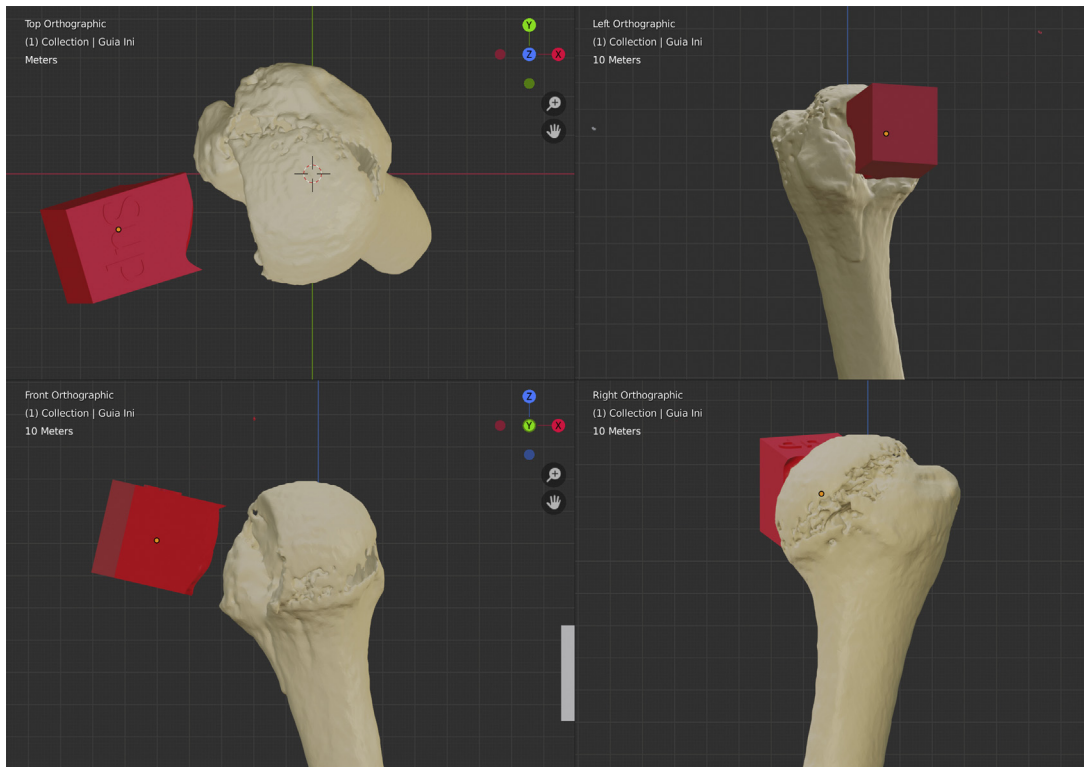


Figure 3 Computer-generated images of the first cutting guide.

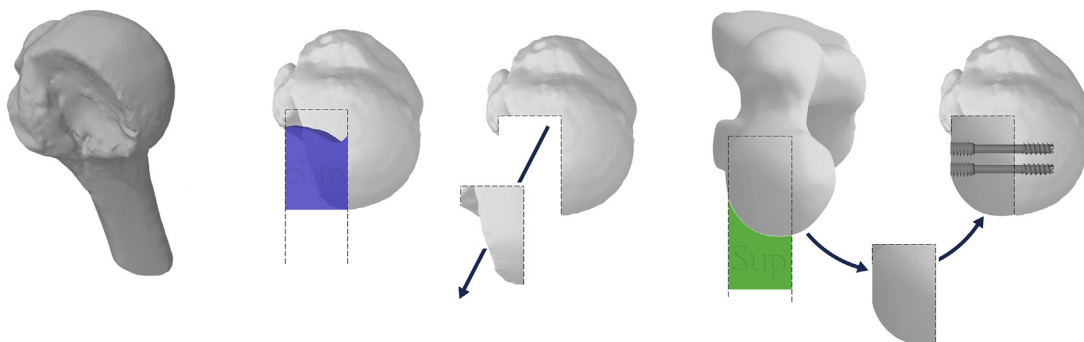


Figure 4 Use of the cutting guides to resect the defect and trim the allograft to the size of the resected defect.

complementing CT with magnetic resonance imaging to enable the recognition of associated lesions in the labrum or joint capsule.²⁰

Tomography software facilitates the acquisition of accurate measurements. Here, the percentage of the humeral head affected by the lesion was assessed using the method described by Moroder et al¹⁶ to determine whether the reverse Hill-Sachs lesion should be treated surgically. After we established that the lesion had a significant impact and that the defect was compatible with an engaging lesion as defined by Burkhart et al,² surgical repair was selected.

Diverse treatment options were proposed,^{5,7,8,10,12,14,19} but a literature review, consideration of the patient's characteristics, and previous experiences of the authors led to the decision to reconstruct the reverse Hill-Sachs lesion using an osteochondral graft. Several groups have reported positive results for this procedure and a relatively low complication rate.^{5,7,14} Gerber and Lambert⁷ also reported fair long-term results, with 1 patient (out of 4) showing

avascular necrosis 6 years after the treatment. This technique preserves the patient's anatomy, not requiring transpositions or myotendinous alterations, and therefore allows other techniques to be reserved as potential salvage procedures in case of failure.¹⁵

Several companies offer custom implants manufactured from CT scans. In addition, some cutting templates are printed using additive technology, which reduce surgical times and individualize bone resections. Because of the popularization of these technologies, certain orthopedic surgery departments have incorporated this working method and prepare ad hoc surgical templates for their patients.^{13,22}

In this case, manufacturing 2 cutting guides reduced the surgical time and bone resection requirement while improving precision in trimming the allograft. By using free software and a low-cost commercial printer, any hospital can tailor certain orthopedic treatments to individual needs. The good results obtained in this case and other cases lead us to believe that this approach has positive effects for patients.



Figure 5 Cutting guides printed in medical resin.

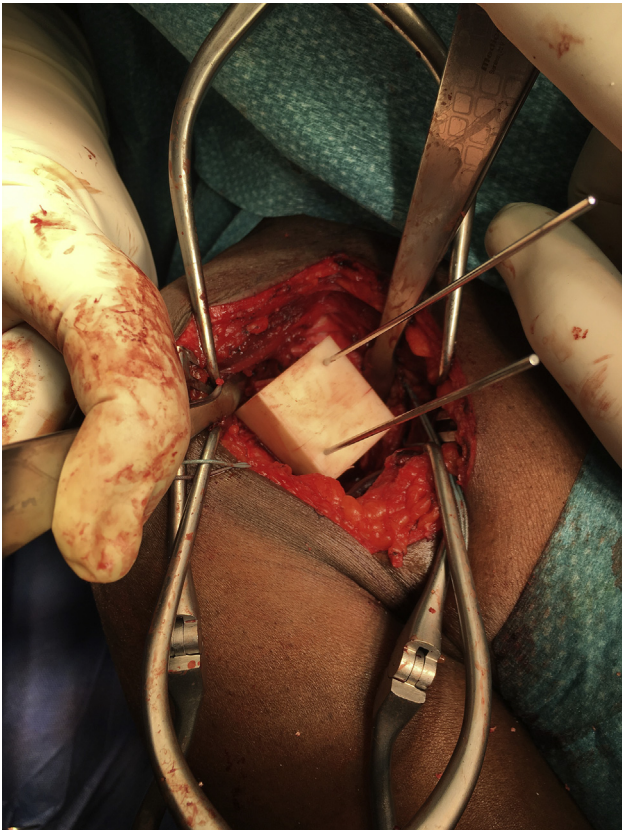


Figure 6 Intraoperative image of the cutting guide used for reconstruction of the reverse Hill-Sachs lesion.

To conclude, we note that 3D modeling software packages and additive printers, as they become increasingly popular, provide tools for orthopedic surgeons that can improve their patients' clinical outcomes. Similar to any new technique, the use of such tools requires personal effort and overcoming a learning curve, but we believe that avoiding these challenges would not be ethically acceptable if we are aware of the advantages that 3D planning and printing provide.

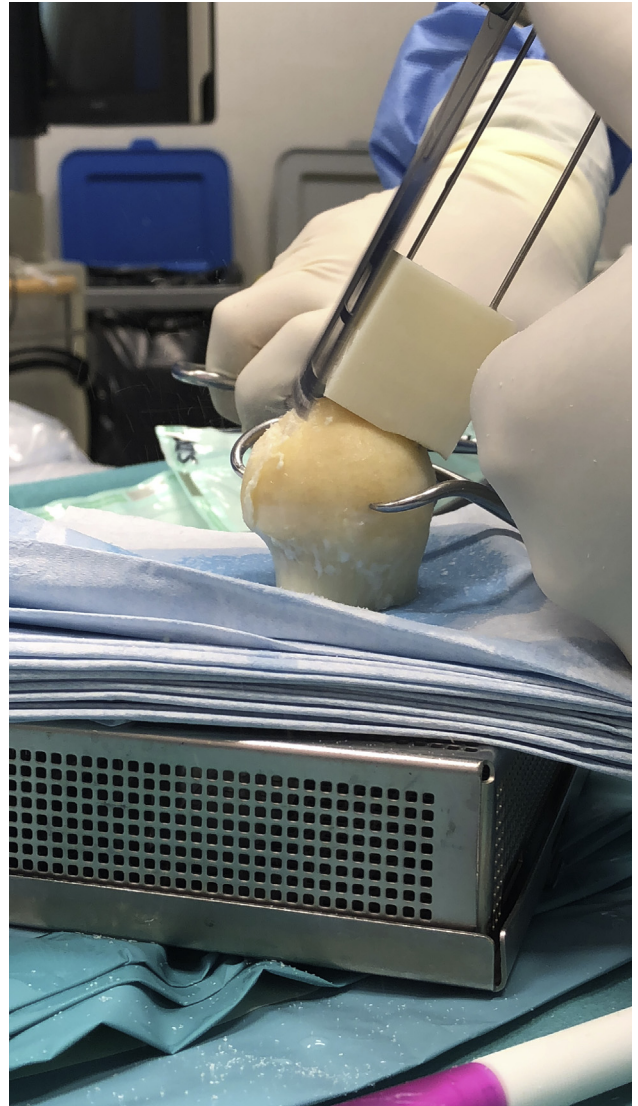


Figure 7 Intraoperative image of the cutting guide used to trim the allograft to the desired size.

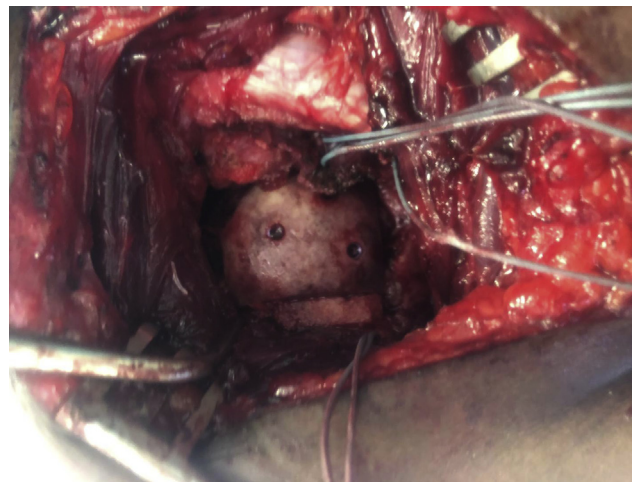


Figure 8 Intraoperative image of the graft fixed with cannulated screws.

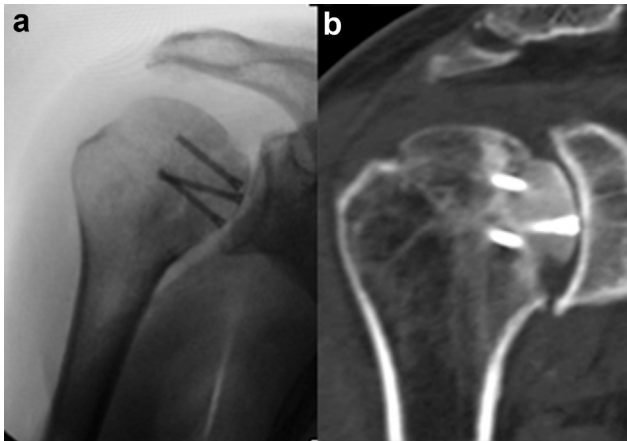


Figure 9 (a) Radiograph showing the final positioning of the allograft and its fixation with screws. (b) CT scan 1 year after surgery.

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