

# Unilateral C1 split fracture osteosynthesis using a patient-specific three-dimensional-printed guide: Technique report

## ABSTRACT

Split-type C1 lateral mass fractures have a propensity for progressive fracture displacement. Since almost all cases end up showing progressive fragment diastasis, many authors recommend early surgical treatment. However, placing a C1 lag screw through a C1 split fracture is a challenging task. To overcome this, we designed a patient-custom three-dimensional (3D)-printed guide plate. We present the case of a 57-year-old female patient with a C1 lateral mass split fracture. Considering the amount of fragment translation, primary osteosynthesis was proposed. To purchase both fragments, placement of a lag screw was assisted intraoperatively by a custom 3D-printed composite guide plate, which enabled us to accurately place the screw. After an uneventful procedure, the patient was discharged from hospital after 72 h. Computed tomography scan performed at 12 months showed good fracture consolidation. The use of a patient-specific guide to place a lag screw through a split fracture of the atlas proved to be a safe, accurate, and inexpensive alternative to intraoperative imaging integrated with image-guided surgery.

**Keywords:** C1 fracture, lag screw, sagittal split fracture, spine model, three-dimensional printing, unilateral C1 fixation

## INTRODUCTION

A subset of C1 lateral mass fractures with intact transverse atlantal ligament have a propensity for progressive displacement. These fractures are known as split-type lateral mass fractures.<sup>[1]</sup> Considering that almost all cases end up showing progressive fragment diastasis, many authors recommend early surgical treatment.<sup>[1-4]</sup> Since C1 osteosynthesis spares motion, it has become the ideal treatment strategy when feasible. However, placing a C1 lag screw through a C1 split fracture is a challenging task. To overcome this, we designed a patient-custom three-dimensional (3D)-printed guide plate, which proved very helpful in treating a patient with a C1 split fracture. We describe here this alternative and accurate low-cost technique.

## CASE REPORT

We present the case of a 57-year-old female patient with a history of osteoporosis, who suffered a neck trauma after

falling from a church stair. She was referred to our hospital the following day on a Philadelphia collar. The patient came to our emergency department in cervical pain, relieved only by the collar. Physical examination showed limited head rotation and subtle cock-robin deformity. Computed tomography (CT) scan was ordered, which showed a right C1 lateral mass split fracture, with a 7-mm diastasis of the bony fragments. MRI performed at admission verified

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preservation of the transverse ligament. Considering the amount of fragment displacement and the already subtle deformity, primary osteosynthesis was proposed [Figure 1]. Given the required angle, the placement of the screw was assisted intraoperatively by a custom 3D-printed composite guide plate. The institutional review board approved this study (IRB approval # 01/0100).

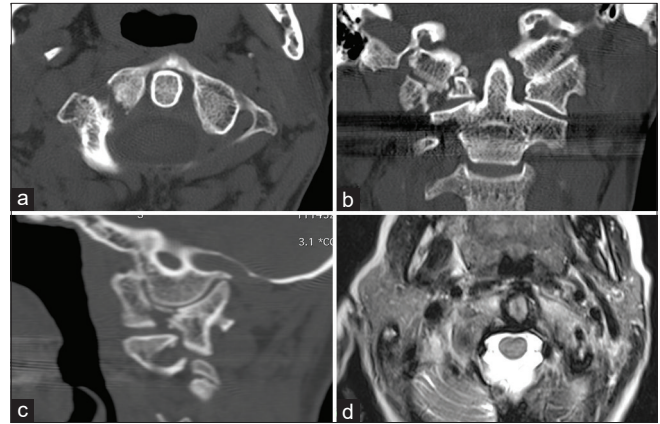
For the design of the guide, a head-and-neck CT scan was performed with the following resolution:  $512 \times 512 \times 607$ , voxel size: x: 0.428 mm, y: 0.428 mm, and z: 0.63 mm. Surgical preoperative planning was conducted using Tracker Navigation System (Fi.Me. - Física Médica S.R.L., Córdoba, Argentina, and Mevis Ltda, SP, Brazil). Segmented anatomy and screw trajectory were exported in STL format. Using CAD software Autodesk Meshmixer (2017 Autodesk, Inc.), a personalized guide was designed [Figure 2]. Boolean difference function was used to define the shape of the surface of the guide supported by vertebrae. To build the biomodel and guide, we used a fused deposition modeling printer (Ultimaker 3, Ultimaker BV, Utrecht, The Netherlands). Finally, a polylactic acid (a nontoxic and biodegradable plastic) guide was printed.

### Technique

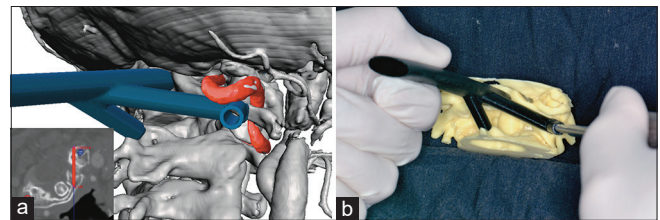
Under general anesthesia, the patient was placed prone over a Wilson frame, with her head secured on a Mayfield head holder under 5-kg cephalic traction. Scalp and extremity electrodes for intraoperative evoked potentials motor evoked potentials (MEP) and somatosensory evoked potentials (SSEP) were placed. Midline incision was made frominion to C4, exposing the lower portion of the right occipital bone and the posterior arch of the atlas. Next, the custom guide plate was placed as a guide for the pilot hole at the lateral mass of C1. After performing a separate 1-cm extreme lateral right skin incision, a 2-mm K-wire was progressed with a low-speed drill through the guide. The direction in both planes was verified with a C-arm. After the guide was removed, a  $3.5 \times 30$  mm cannulated lag screw (Bioprotece S.A., Villa Ballester, Buenos Aires, Argentina) was placed over the K-wire and gradually progressed. Once the anterior bone fragment was purchased, the wire was then removed, and the screw was finally tightened. No MEP or SSEP alterations were seen throughout the procedure. The surgery time was 190 min. After the procedure, the patient was extubated, and no neurological deficit was recorded.

The patient had an uneventful postoperative course, referring a marked improvement in pain during her recovery in our institution. Postoperative CT was performed, showing proper implant position. The patient was discharged from hospital after 72 h in a Philadelphia cervical collar. CT scan performed at 12 months showed good consolidation of the right lateral

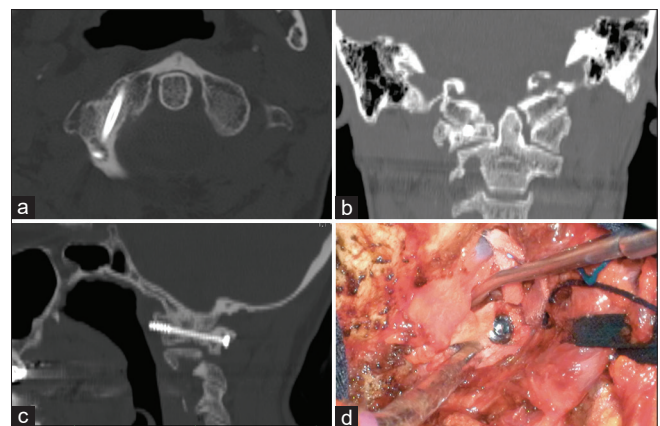
mass of the atlas [Figure 3]. After 18 months, the patient continues asymptomatic, showing minimal head deformity and normal head rotation [Figure 4].



**Figure 1:** (a) Preoperative axial computed tomography scan showing a right lateral mass sagittal split fracture. The measured gap was 7 mm. (b) Coronal computed tomography scan. Note the right condyle “pushing down” between the two fragments, a usual finding in these types of fractures. (c) Sagittal computed tomography scan. (d) Axial T2-weighted image demonstrating an intact transverse ligament, which appears hypointense



**Figure 2:** (a) Preoperative plan showing the PLA guide plate being placed as a guide for the pilot hole at the lateral mass of C1. (b) PLA guide plate model. The guide rests on three points of the bony anatomy and has an arm to handle it. The arm resting on the lateral mass contains the guide for the screw to be passed through



**Figure 3:** (a) One-year postoperative axial computed tomography scan showing fusion across the screw. (b) Postoperative coronal computed tomography scan. Persistent deformity of the craniocervical junction is observed. (c) Parasagittal computed tomography scan showing adequate restitution of the C1 lateral mass upper articular surface. (d) Intraoperative microscope photograph showing the screw in place while a Penfield dissector is lifting the vertebral artery



**Figure 4:** Postoperative pictures of the patient taken 18 months postoperatively. She is able to freely rotate her head both sides

## DISCUSSION

Primary surgery is indicated in cases where a unilateral lateral mass sagittal split fracture is evident. This fracture type is characterized by a large lateral fragment of the lateral mass that is completely separated from the anterior and posterior arch. Recent studies have indicated that this fracture type, if treated conservatively, often results in a lateral displacement of the lateral fracture fragment accompanied by a subluxation of the occipital condyle, clinically associated with nonradiating neck pain, head malposition (cock-robin deformity), and diminished head rotation.<sup>[1]</sup> Although occipitocervical fusion was the treatment of choice in the first described cases, a unilateral lag screw osteosynthesis has been recently described in more oblique split fracture's patterns without comminution.<sup>[5,6]</sup>

As stated by Tabbosha *et al.*,<sup>[5]</sup> lag screw placement through a split fracture is only feasible with the assistance of intraoperative 3D surgical imaging system. Since intraoperative imaging integrated with image-guided surgery is beyond economic possibilities in many developing countries, patient-specific 3D-printed guides are a low-cost solution to this problem.

Patient-specific 3D-printed guides are not a novel concept. However, it has been mainly used to treat deformity cases.<sup>[7,8]</sup> Its use in the cervical spine has been studied mainly in the subaxial spine. Lu *et al.* reported the use of these templates for 88 cervical pedicle screw placement and no misplacement was found.<sup>[9]</sup> The same author also reported the placement of C2 laminar screw using the same technique in another study and found all screws in perfect placement.<sup>[10]</sup> However, we have not found the use of a patient-specific 3D-printed guide to treat a C1 split fracture.

Finally, and though some authors suggest they use intraoperative imaging integrated with image-guided surgery for safe placement of the lag screw only if a percutaneous

technique is used,<sup>[6]</sup> we believe that the close proximity of the vertebral artery should prompt the surgeon to use some sort of guidance even in open cases.

The use of a patient-specific guide to place a lag screw through a split fracture of the atlas proved to be a safe, accurate, and inexpensive alternative to intraoperative imaging integrated with image-guided surgery.

## Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the legal guardian has given his consent for images and other clinical information to be reported in the journal. The guardian understands that names and initials will not be published and due efforts will be made to conceal identity, but anonymity cannot be guaranteed.

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Nil.

## Conflicts of interest

There are no conflicts of interest.

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