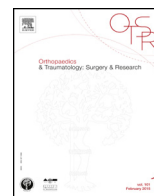




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Technical note

Application of 3D printing for treating fractures of both columns of the acetabulum: Benefit of pre-contouring plates on the mirrored healthy pelvis



P. Upex, P. Jouffroy, G. Riouallon*

Service d'orthopédie, groupe Hospitalier Paris Saint-Joseph, 185, rue Raymond-Losserand, 75674 Paris, France

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ABSTRACT

Acetabular fractures can be challenging to treat, in part because the shape of the fixation plates needs to be adjusted during the surgical procedure. One possibility is to generate a model of the uninjured half of a fractured pelvis with 3D printing, and then pre-contour the fixation plates preoperatively on this model. The purpose of this technical note is to describe how we used 3D printing as an aid to treat acetabular fractures. The quality of the fracture reduction, fracture fixation and time savings were evaluated. Three-dimensional reconstructions of the preoperative CT scan of the pelvis were exported with OsiriX™ software, mirrored with Meshmixer™ software and then printed in polylactic acid (PLA). Two fracture fixation plates were pre-contoured on the printed hemipelvis and then sterilized. No additional intraoperative contouring was needed. Anatomical reduction was obtained with an estimated 30-minute time saving and € 6 consumables cost.

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1. Introduction

The possible medical applications of 3D printing have grown as this technology has become more accessible financially and technically. Printed 3D models have been used for the preoperative planning of thoracic surgery [1], the manufacturing of surgical instruments [2,3], and the diagnosis [4,5] and manufacturing of joint implants [6].

Acetabular fractures are difficult to treat and require specialized care by a skilled surgical team [7,8]. The exposure provided by anterior approaches (ilioinguinal or modified Stoppa) and by posterior approaches is limited and open fixation requires that plates to be tailored to the anatomy of the ilium and ischium in all three planes [9–12]. Intraoperative contouring of these plates is time-consuming and is inevitably not perfect because of the limited visibility provided by the surgical approaches. We will describe a reproducible method in which 3D printing was used in a patient who was undergoing surgery for an acetabular fracture and for whom the plates were shaped preoperatively on a 3D-printed model of his pelvis.

2. Surgical technique

A 39-year-old male had a closed fracture of both columns [13] of his right acetabulum caused by a gas main explosion. The displaced fragments were mainly in the posterior column and quadrilateral surface. We decided to carry out a two-stage procedure: an anterior stage using the ilioinguinal approach to reduce and fix the anterior column and quadrilateral plate, and then a posterior stage using the Kocher-Langenbeck approach to reduce and fix the posterior column and roof.

We started by deleting the femurs in the DICOM files of the CT scan workstation (Advantage Workstation, GE Healthcare, Chicago, IL, USA). With the DICOM files, 3D volumetric reconstruction and surface rendering (300 threshold) of the fractured hemipelvis and healthy hemipelvis were done with OsiriX™ software (Pixmeo, Geneva, Switzerland). These were exported as STL files for Meshmixer™ software (Autodesk, San Rafael, USA) (Fig. 1). The healthy hemipelvis was mirrored (reversed horizontally) and 3D printed along with the fractured hemipelvis (Fig. 2) with a 3D printer (Ultimaker™, Geldermalsen, Netherlands) using polylactic acid (PLA) (0.15 mm layer thickness, 100 mm/s extrusion speed, 20% filling).

We used the 3D model of the healthy hemipelvis to pre-contour two plates: a 10-hole EL R108 plate for the anterior column and an 8-hole EL R108 plate for the posterior column (Stryker, Kalamazoo, USA) (Fig. 3). These plates were then sterilized. We assumed that

* Corresponding author.

E-mail address: griouallon@hpsj.fr (G. Riouallon).



Fig. 1. Example of DICOM images after removal of femoral heads and 3D surface rendering of both fractured and non-fractured hemipelvis with OsiriX software™ (Pixmeo, Geneva, Switzerland).

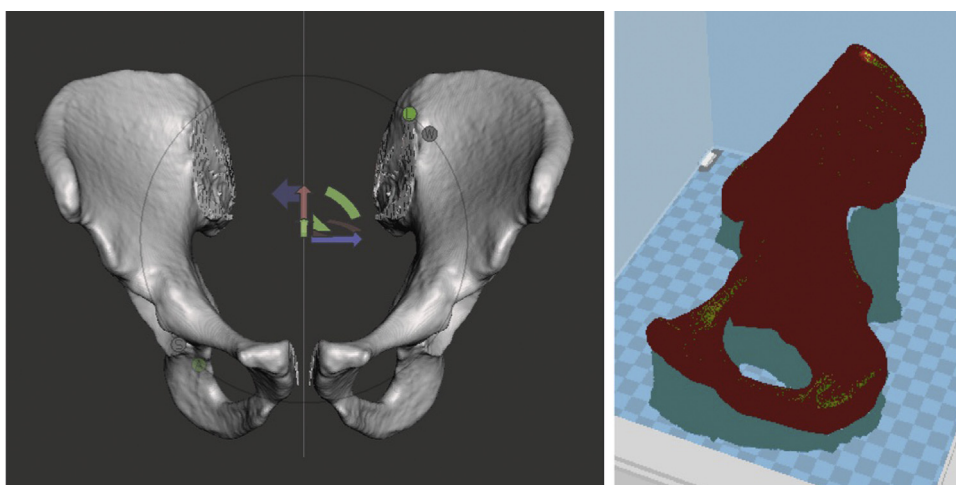


Fig. 2. Mirroring of the non-fractured hemipelvis with Meshmixer™ and view of 3D printing in the splicer (Cura™, Ultimaker, Geldermalsen, Netherlands).

the healthy hemipelvis was anatomically symmetric to the fractured half. However, since the fractured hemipelvis does not have the exact same shape as the healthy hemipelvis, the plate-shaping step requires some approximation.

The procedure was performed the next day by an experienced surgeon [14] who satisfactorily reduced and fixed the fracture. The two plates were applied to the patient without additional modifications. A second posterior plate was added to complete the roof fixation. We estimated that this pre-contouring process saved 30 minutes of operating room time and cost € 6 in plastic consumables. The postoperative course was the customary one, with no weight-bearing for 45 days and discharge to home on the fifth postoperative day. Postoperative X rays and CT scans are shown in Fig. 4.

3. Discussion

Several teams have described the use of 3D planning [15,16] and more specifically 3D printing for treating acetabular fractures [17–19]. An increasing number of publications, both in scientific journals and the public media, have featured medical applications of 3D printing [20]. All of them have mentioned better understanding of the fracture pattern by the surgeons and patients, along with shorter operating time. In our case, we estimated the time savings at 30 minutes, for an € 6 expenditure in plastic consumables.

For now, the limiting factor is the time needed to print a full-size (1:1 model) of the hemipelvis – 24 hours in this case. This delayed the treatment by 48 hours (including the time needed to sterilize the plates). Although this delay is not a concern for acetabular fractures in which surgery is recommended 5 to 10 days after the injury event, it could be an obstacle for other fractures that require more urgent surgical treatment (e.g., tibial plateau fractures).

There are numerous applications of 3D printing in surgery, especially orthopedic surgery. Migaud et al. [21] used this technique back in 1997 to plan a complex osteotomy procedure on a proximal femur. In 2002, Brown et al. [22] described the manufacturing of an alignment device for the screw fixation of posterior wall fractures of the acetabulum. Fuller et al. [2] used 3D printing to design a specialized reduction clamp for phalanx fractures. Rankin et al. [3] described using 3D printing to manufacture surgical instruments in military field hospitals. Evill [23] used this technology to design custom-made support braces for fractures.

Our work confirms the feasibility of 3D printing applications [17,18] and provides a clear method that makes this technology accessible to everyone.

The future of surgery will inevitably pass through 3D, whether by 3D printing techniques or computer-assisted systems that use virtual reality and navigation [24]. The applications will continue to expand as these technologies become more widespread and their cost goes down. A commercial 3D printer costs between € 1500 and

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